Sewage Works

A BASIC LAW FOR THE PERFORMANCE OF BIOLOGICAL FILTERS

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Recent discussions of high-rate trickling filters, notably the work of the Upper Mississippi River Basin Committee (1) and the report of the National Research Council (2), have stimulated the search for a basic expression suitable for the explanation and prediction of the performance of biological beds. In this paper there is presented a theory applicable to all biological beds, low-rate as well as high-rate trickling filters, namely:

The rate of extraction of organic matter per interval of depth of a biological bed is proportional to the remaining concentration of organic matter, measured in terms of its removability.

This, it is recognized, is similar to the biological oxidation law developed by Phelps (3) and may be expressed in differential form as

$$-\frac{dL}{dD} = KL.$$

Integrating to

$$\log_e \frac{L_D}{L} = -KD$$

or

$$\log \frac{L_D}{L} = -0.434KD = -kD$$

whence

$$\frac{L_D}{L} = 10^{-kD} \qquad (1)$$

where L represents the total removable fraction of B.O.D.; D is depth; and L_D represents the corresponding quantity of removable B.O.D. remaining at depth D. The ratio L_D/L is the proportion of the total removable fraction remaining in the passing liquor at depth D, and $1 - L_D/L$ is the proportion extracted.

The Removable Fraction

Not all of the B.O.D. applied to a biological bed is removable; hence, there is a residual which is not extracted even by repeated passages or by a very deep bed. The magnitude of the total removable fraction is dependent upon a combination of variable factors.

It is a well-known fact that B.O.D. in dissolved form is the most difficult to remove and requires protracted intimate contact with zooglea for its extraction. The removable fraction L is dependent, therefore, upon the proportion of the B.O.D. in suspended and colloidal form as distinct from that in true solution.

The mass of the zooglea in the bed and its sloughing, as well as the opportunity for and period of contact, are dependent upon the hydraulic rate of passage of the liquid medium through the bed. The removable fraction L can be expected to decrease as the rate of application in m.g.a.d. increases. This is demonstrated by the performance for continuous application to high-rate beds and is confirmed for intermittent application by the experi-

mental work of Levine and associates (4). However, data are too meager at this time to establish a quantitative relationship between the removable fraction L and hydraulic loading.

Obviously, there must be some limit to the quantity of B.O.D. which can be assimilated by the biological life of the bed. The limiting B.O.D. load, then, must be a function of the rate of biological oxidation and the storage capacity for accumulation of B.O.D. within the bed. If the rate of extraction from the applied load exceeds the rate of assimilation, then accumulation will reach a point where bed storage capacity of the zooglea is exceeded and the excess will be carried through, thereby increasing the residual in the effluent and decreasing L. Since biological oxidation is a temperature function, the limiting load is lower during cold weather; however, at loadings which come to equilibrium at levels

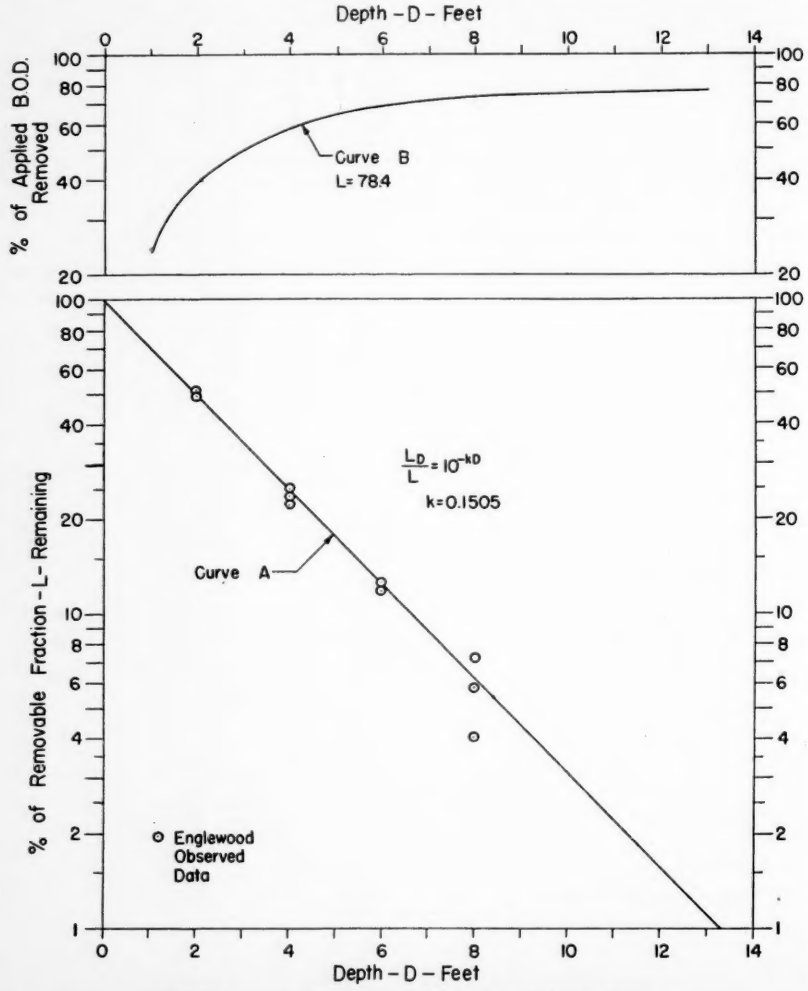

FIGURE 1.—Performance of high-rate trickling filters.

below the limiting storage capacity of the bed, L is unaffected by temperature and is constant for any applied load below the limiting load.

High-Rate Trickling Filters

The logarithmic rate of extraction k and the magnitude of the removable fraction L must be determined experimentally for any particular type of biological bed. Unfortunately, data are meager as to performance of beds at successive intervals of depth. For high-rate trickling filters, observations at 2-ft. intervals in an 8-ft. experimental bed at Englewood, N. J. (5), continuously dosed at a hydraulic rate of approximately 20 m.g.a.d., indicated an extraction of B.O.D. in successive 2-ft. intervals of 50 per cent of that removed in the preceding interval. With these data and reported operating results (1) (6) of high-rate installations, k, the logarithmic rate of extraction, and L, the removable B.O.D. fraction, are estimated at 0.1505 and 0.784, respectively.

Performance Curves

Using these values of k and L, Figure 1 is a graphical representation of expected performance of biological beds continuously dosed at approximately 20 m.g.a.d. Curve A represents the per cent of the removable fraction L remaining in the passing liquor at any depth of bed D. It also represents the extraction of B.O.D. in succeeding depth intervals expressed as a percentage of that extracted in the preceding interval. For a bed of given depth this is equivalent to the extraction in succeeding passages, expressed as a percentage of that extracted in the preceding passage. Curve B represents the removal effected in passage through a bed of depth D expressed as a percentage of the B.O.D. load *applied* to the bed. Removals represent the combined performance of the bed and its final sedimentation tank, and applied load is settled sewage, excluding B.O.D. of any recirculated flow.

Figure 2 (based upon Figure 1) shows the performance to be expected of beds of various depths, with loadings and removals expressed in pounds of 5-day B.O.D. of settled sewage (exclusive of B.O.D. contained in any recirculated flow) applied per day per unit surface area of bed.

Limiting Load

Performance of high-rate beds over a wide range of loading per unit of bed area confirms that L, and therefore the removal for a bed of any given depth, remains constant up to the limiting loading. The limit appears to be in the vicinity of 1 lb. of 5-day B.O.D. per square foot per day at a temperature near 30° C.

Bed Storage at Equilibrium

The equilibrium accumulation of B.O.D. stored in the bed in relation to daily extraction by the bed and the rate of biological oxidation are given by

$$L_e = \frac{L_p}{2.3k_1} \qquad (2)$$

in which L_e represents the accumulation of B.O.D. within the bed, L_p the daily extraction by the bed, and k_1 the logarithmic rate of biological oxidation at the particular temperature involved. At a temperature of 29° C., using an applied load of 1 lb. per sq. ft. per day, the maximum removal L would be 0.784 lb. per sq. ft. per day (Figure 2); and L_e, the maximum accumulation, would be

$$L_e = \frac{0.784}{2.3 \times 0.1505} = 2.26 \text{ lb. per sq. ft.}$$

This applies to a bed of infinite depth; the accumulation for beds of other depths will be proportional to their respective extractions.

Since a time element is involved in

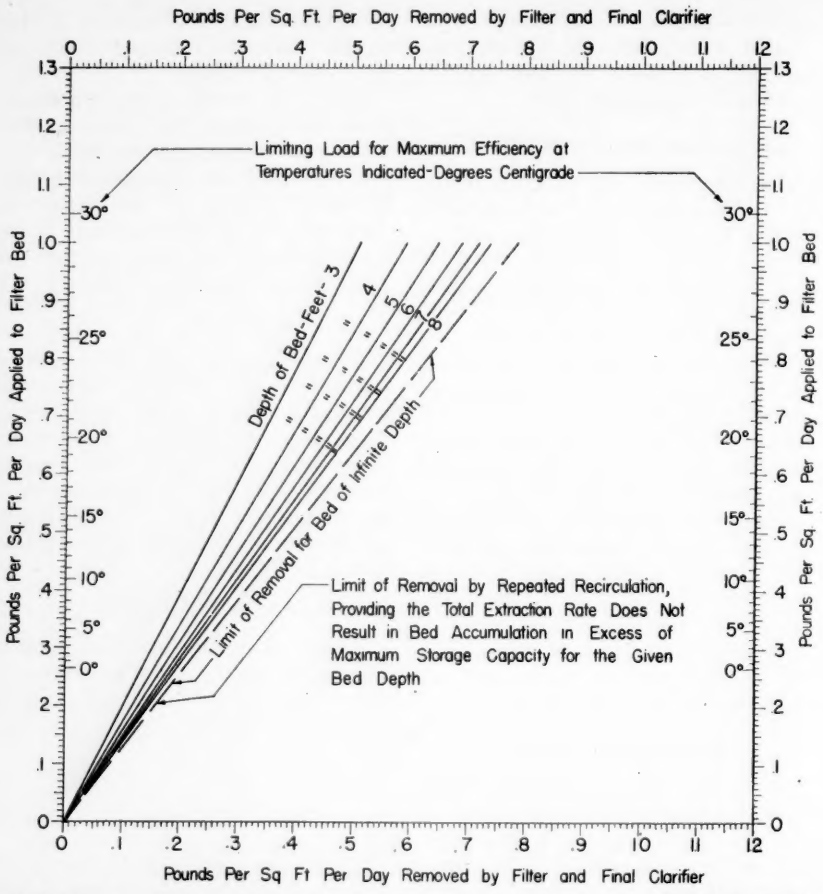
Pounds Per Sq. Ft. Per Day Removed by Filter and Final Clarifier
Pounds Per Sq. Ft. Per Day Applied to Filter Bed
Limiting Load for Maximum Efficiency at Temperatures Indicated-Degrees Centigrade
30°
25°
20°
15°
10°
5°
0°
Depth of Bed-Feet-3
" " " " 4
" " " " 5
" " " " 6
" " " " 8
" " " " ∞
Limit of Removal for Bed of Infinite Depth
Limit of Removal by Repeated Recirculation, Providing the Total Extraction Rate Does Not Result in Bed Accumulation in Excess of Maximum Storage Capacity for the Given Bed Depth

FIGURE 2.—Relation between loading and removal by high-rate trickling filter with final clarifier. (Expressed in terms of pounds 5-day B.O.D. of settled sewage, exclusive of B.O.D. of recirculated flow.)

building up the equilibrium accumulation (99 per cent reached in approximately 13, 20 and 32 days at 29°, 20° and 10° C., respectively), hourly and daily variations for short periods in excess of the limiting load as an average may be applied without materially increasing accumulation and, therefore, without appreciable loss of efficiency. This stabilizing influence of bed accumulation serves as a shock absorber to sudden changes in load, and is one of the most valuable characteristics of all trickling filters.

Effect of Temperature on Limiting Load

If, under conditions of 29° C., 2.26 lb. per sq. ft. represents the maximum allowable accumulation of B.O.D without a decrease in L and efficiency, it is obvious that as the temperature drops and the biological rate of oxidation k_1 diminishes, the daily removal, and hence the daily applied load, must be reduced in accordance with

$$L_p = 2.26 \times 2.3 \times k_T$$
$$(k_T = k_{20} \times 1.047^{T-20}).$$

Hence, to preserve maximum efficiency with maximum daily loading it is necessary to reduce the daily applied load from 1.0 lb. per sq. ft. at 29° C. to 0.663 lb. at 20°, to 0.420 lb. at 10° and to 0.265 lb. at 0° C. These limits of loading are identical for beds of all depths and are designated on Figure 2, arranged to permit interpolation for any temperature between 0° to 30° C.

Efficiency Under Excess Loading

While efficiency remains constant at its maximum for B.O.D. loadings below the limiting load, data are insufficient at this time to determine the exact nature of the decline in efficiency under excess loading. It appears that for normal biological oxidation of sewage the maximum removal at equilibrium accumulation remains constant with a limited extent of excess loadings, ultimately followed by a rapid decline to complete breakdown. This implies that when the maximum removal is reached, any increment of excess loading applied simply passes through the bed. The efficiency for any depth and temperature at excess loading, therefore, is the ratio of the maximum B.O.D. removal (at the specified depth and temperature) to the total applied load. Thus, for a 3-ft. bed at 29° C., maximum removal is 0.508 lb. per sq. ft. at an applied load of 1.0 lb. per sq. ft., a maximum efficiency of 50.8 per cent. At a loading of 1.3 lb. per sq. ft. at the same temperature, efficiency would decrease to 0.508/1.3 or 39.1 per cent. Similarly, if the temperature dropped to 10° C. the maximum removal for the 3-ft. bed would be 0.214 lb. per sq. ft. at a loading of 0.420 lb. per sq. ft., or 50.8 per cent efficiency, but if the load were 1.3 lb. per sq. ft., efficiency would decrease to 0.214/1.3 or 16.5 per cent.

Recirculation and Series Treatment

Recirculation or two-stage series treatment can be evaluated readily in terms of removal through successive depths (Figure 1). Recirculation is usually expressed as R/I, the ratio of the volume of recirculated flow R to the volume of influent to the plant I. Thus an R/I of 1.0 is equivalent to passing the influent I through the filter twice, which is tantamount to passing I once through two such successive depth intervals. An R/I of 1.5 is equivalent to passing I through twice, and 0.5 of I through 3 times. Similarly, if the filters are of the same depth, two-stage series treatment and any recirculation in the second stage is equivalent to additional passages by recirculation through the first stage. The limit of removal by repeated or successive passages by recirculation or series treatment on filters of the same depth is the total removable fraction L, providing the total extraction rate does not result in bed accumulation in excess of maximum storage capacity. From Figure 2 it is evident that where deep filters of 6 to 8 ft. are employed, recirculation or series treatment can produce but small additional removals over that of a single pass; but for shallow filters (3 ft.) there is a substantial increment to be obtained. Since all depths are bound by the same limit, L, decisions as to the adoption of recirculation or series treatment are governed primarily by economic considerations.

Recirculation and series treatment, however, are effective only up to the limit at which the total rate of extraction is at or below that producing the maximum allowable accumulation L_e for a given depth of bed.

Low-Rate Trickling Filters

Similarly, for the conventional low-rate beds intended for complete treatment, the logarithmic rate of extraction k and the magnitude of the removable fraction L in equation (1) are determined from observed performance. Observations at 2-ft. intervals in a 10-ft. bed reported by Buswell

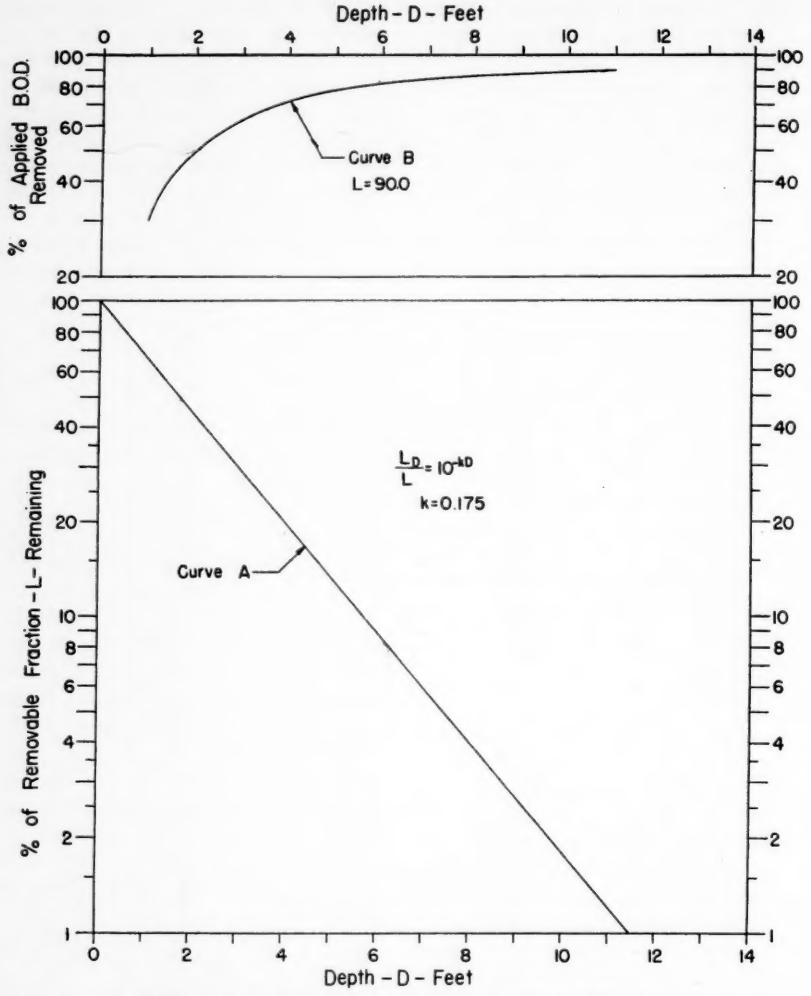

FIGURE 3.—Performance of low-rate trickling filters.

and associates (7) and performance of conventional filters reported by Childs and Schroepfer (8) and by the Committee on Sanitary Engineering, National Research Council (2), indicate approximate values of 0.175 for k and 0.90 for L, with hydraulic rates of 2 to 6 m.g.a.d. applied intermittently, as compared with k of 0.1505 and L of 0.784 for high-rate beds. The applied B.O.D. is settled sewage and the removable fraction is based upon the combined action of the filter and its final sedimentation tank.

Performance Curves

Using k of 0.175 and L of 0.90, Figure 3 is a graphical representation of expected performance of low-rate beds. Curve A represents the basic law and shows the percentage of the total removable fraction (L) which remains

in the liquor after passage through depth (D); while Curve B shows the removal effected in passage through depth (D) expressed in terms of B.O.D. load *applied* to the bed. The curves express removal in terms of the combined performance of the filter and its final sedimentation tank, and the applied load is in terms of settled sewage.

For conventional beds with sewage of normal strength, usually the influence of hydraulic loading will begin to produce a decrease in the removable fraction L before the limiting B.O.D. load is reached. It is to be expected that with lower daily hydraulic rate, bed storage capacity for accumulated B.O.D. is greater than that of high-rate beds. Data are too meager at this time, however, to permit determination of the limiting B.O.D. loading and its corresponding maximum accumulation L_e. When such data become available, curves similar to Figure 2 can be determined for low-rate beds. Probably, most conventional low-rate beds operate well below their limiting B.O.D. loading and hence, accumulation is below bed capacity even during cold weather. If accumulation remains below bed storage capacity, efficiency remains constant at its maximum for a bed of given depth, as shown in Figure 3.

Application to Design

As an illustration of the application of these principles, let it be assumed that 4 m.g.d. of a raw sewage of 215 p.p.m. 5-day B.O.D., to meet stream requirements, must be reduced to an effluent discharge not exceeding 1,325 lb. per day during summer and 2,900 lb. per day during winter. The temperature of the sewage in summer is 29° C. and drops to 10° C. in winter. It is stipulated that hydraulic loading shall not exceed 30 m.g.a.d., no recirculation shall be employed, and not exceeding 30 per cent reduction in load shall be credited to primary sedimentation. The depth and area of bed required would be determined as outlined below:

Settled sewage B.O.D. applied to bed	5,000	lb. per day
Stipulated effluent B.O.D.	1,325	lb. per day
Required B.O.D. removal, filter and tank	3,675	lb. per day
Required B.O.D. removal, filter and tank	73.5	per cent
Required bed depth (Figure 1)	8	feet
Maximum allowable applied loading 29° C. (Figure 2)	1.0	lb/sq. ft.
Required area, B.O.D. basis	5,000	sq. ft.
Required area, hydraulic basis	5,810	sq. ft.

The hydraulic loading is controlling, and the B.O.D. loading becomes $5{,}000/5{,}810 = 0.86$ lb./sq. ft. Before adopting this, however, winter conditions must be investigated.

During cold weather the temperature of the sewage is 10° C. and the stream will accept 2,900 lb. of 5-day B.O.D. per day. This calls for a reduction of only 42 per cent of the B.O.D. of the settled sewage by the filter and secondary sedimentation tank.

At 10° C. the limiting loading for maximum efficiency (73.5 per cent) is only 0.420 lb. per sq. ft. (Figure 2), and the removal at that loading would be $0.735 \times 0.420 = 0.309$ lb. per sq. ft. If, in accordance with the principles previously discussed, this value, 0.309, be considered fixed under conditions of overloading, and if it now represents 42 per cent of the total applied load, the allowable winter B.O.D. loading becomes $0.309/0.42 = 0.735$ lb. per sq. ft. and the corresponding area (B.O.D. basis) becomes $5{,}000/0.735 = 6{,}800$ sq. ft. With this area the hydraulic rate is

$$\frac{4 \times 43{,}560}{6{,}800} = 25.6 \text{ m.g.a.d.}$$

which is within the 30 m.g.a.d. limit. The winter conditions are controlling in this situation, and 6,800 sq. ft. of 8-ft. bed is required.

As a further illustration, if in the above example it had been stipulated that recirculation may be employed during summer but not during winter, various combinations of bed depth, area, and summer recirculation ratio could meet the stream requirements. For example, if a 4-ft. bed is selected for a trial design:

Summer requirements with recirculation:		
Summer B.O.D. removal required (0.735 × 5,000)	3,675	lb. per day
First pass through 4-ft. bed, Figure 1-B (0.588 × 5,000)	2,940	lb. per day
Balance to be removed by recirculation	735	lb. per day
Second pass through 4-ft. bed, Figure 1-A (0.25 × 2,940)	735	lb. per day
Balance to be removed by third pass	0	
Recirculation ratio R/I	1.0	
Allowable B.O.D. extraction 4-ft. bed, 29° C., Figure 2	0.588	lb. per sq. ft.
Allowable B.O.D. loading with R/I of 1.0 (0.588/0.735)	0.80	lb. per sq. ft.
Required area, B.O.D. basis (5,000/0.8)	6,250	sq. ft.
	0.1433	acres
Hydraulic loading including recirculation (8/0.1433)	55.8	m.g.a.d.
This is in excess of the 30 m.g.a.d. limit, hence:		
Required area hydraulic basis (8/30)	0.2667	acres
	11,620	sq. ft.
B.O.D. loading (5,000/11,620)	0.430	lb. per sq. ft.
Check for winter requirements without recirculation:		
Maximum removal for 4-ft. bed, 10° C., Figure 2	0.247	lb. per sq. ft.
Allowable load, 4-ft. bed, 10° C., for maximum efficiency	0.420	lb. per sq. ft.
Actual applied load (see above)	0.430	lb. per sq. ft.
Therefore, winter operation is at a slight excess loading, and efficiency is (0.247/0.43)	57.4	per cent

Therefore, 11,620 sq. ft. of 4-ft. bed with a recirculation ratio during summer of 1.0 is necessary to meet summer stream requirements, and this bed without recirculation will meet winter requirements with a margin of excess efficiency.

By the same procedure, if a 5-ft. bed is selected the recirculation ratio may be reduced to 0.788 and the area to 10,380 sq. ft., with winter efficiency without recirculation at 56.3 per cent; for a 6-ft. bed, the recirculation ratio may be reduced to 0.571 and the area to 9,120 sq. ft., with winter efficiency without recirculation at 52.5 per cent. On the other hand, if a 3-ft. bed is selected the recirculation ratio must be increased to 1.75 and the area to 15,970 sq. ft. and, since with this area the winter B.O.D. loading is below the limiting load, the maximum efficiency for a 3-ft. bed, 50.8 per cent, is maintained throughout the year.

Comparison of Observed and Computed Performance

The validity of the basic theory is demonstrated by a comparison between observed and computed performance of biological beds under widely different conditions.

Tables I and II show comparisons for high-rate trickling filters of various depths, in both single-stage and series operation, with recirculation, based upon data reported from military sewage treatment plants by the National Research Council (2). In Table I, for the plant at Fort F. E. Warren, the reported temperature was 52° to 71° F. At the mean temperature of 61.5° F. (16.4° C.) the maximum extraction allowable for maximum bed storage for a 3-ft. bed is 0.286 lb. per sq. ft. This extraction could be accomplished without recirculation at a maximum applied load of 0.286/0.508 = 0.563 lb. per sq. ft., or with R/I of 2.77 (extraction 76.5 per cent) at a maximum applied load

TABLE I.—Comparison of Observed and Computed Performance of Single-Stage, High-Rate Trickling Filters [1]

Plant	Depth (ft.)	R/I	Filter Loading		5-Day B.O.D. Removal by Filter and Final Clarifier (lb./sq. ft./day)	
			M.G.A.D.	5-Day B.O.D. (lb./sq. ft./day)	Observed	Computed[2]
Kessler	3.9	1.26	11.1	0.214	0.184	0.159
Sill	3.25	0.51	16.4	0.481	0.303	0.297
Bragg	3.42	4.15	29.2	0.341	0.275	0.267
Dix	3.75	2.82	14.4	0.200	0.179	0.156
Kearns	3.5	10.50	20.8	0.064	0.057	0.050
Kilmer	3.0	1.86	11.4	0.105	0.071	0.078
Myles Standish	3.0	4.59	14.2	0.140	0.114	0.109
F. E. Warren	3.0	2.77	31.9	0.585[3]	0.295	0.286
Boca Raton	6.0	3.58	14.9	0.160	0.151	0.126
Callan	6.0	0.85	25.7	0.800[3]	0.588	0.538
Carson	7.25	1.55	10.2	0.195	0.161	0.153
Drew	6.0	0.95	18.6	0.268	0.207	0.206
Forrest	6.25	1.72	22.1	0.365	0.255	0.282
Jackson	5.0	1.28	18.1	0.330	0.219	0.252

[1] Observed data from "Sewage Treatment at Military Installations," THIS JOURNAL, **18**, 5, 787 (Sept., 1946); Chapter V.

[2] Computed removals based on Figures 1 and 2, at hydraulic loading of 20 m.g.a.d. Observed and computed removals are directly comparable only at this hydraulic loading; it is to be expected that observed removals are greater than the computed where loading is below 20 m.g.a.d., and less than the computed where the loading is at higher rates.

[3] Overloaded.

TABLE II.—Comparison of Observed and Computed Performance of Two-Stage, High-Rate Trickling Filters [1]

	Depth (ft.)		$(R_1+R_2)/I$	Hydraulic Loading (m.g.a.d.)	5-Day B.O.D. (lb./sq. ft./day)		
	F_1	F_2			Applied to F_1	Removed by Filters and Final Clarifiers	
						Observed	Computed[2]
Gordon	6	6	1.60	7.69	0.146	0.119	0.115
Riley	4	4	4.70	16.70	0.172	0.140	0.135
Roberts	3	3	4.95	31.1 to 45.6	0.650[3]	0.519	0.510
Willow Grove	3	3	4.53	14.7 to 16.2	0.068	0.058	0.053

[1] Observed data from "Sewage Treatment at Military Installations," THIS JOURNAL, **18**, 5, 787 (Sept., 1946); Chapter V.

[2] Computed removals based on Figures 1 and 2, at hydraulic loading of 20 m.g.a.d. Observed and computed removals are directly comparable only at this hydraulic loading; it is to be expected that observed removals are greater than the computed where loading is below 20 m.g.a.d., and less than the computed where the loading is at higher rates.

[3] Assumed 30 per cent removal by primary sedimentation.

of $0.286/0.765 = 0.374$ lb. per sq. ft. Hence the bed is overloaded at an applied load of 0.585 lb. per sq. ft. at 16.4° C. If temperatures were above 26.2° C., the maximum extraction would be 0.448 lb. per sq. ft., and with $R/I = 2.77$ and the applied load of 0.585 lb. per sq. ft., the bed storage would just come to equilibrium at the maximum bed storage value for a 3-ft. bed.

Also in Table I, for the plant at

TABLE III.—Comparison of Observed and Computed Performance of Municipal, Single-Stage, High-Rate Trickling Filters [1]

Plant	Depth (ft.)	*R/I*	Filter Loading		5-Day B.O.D. Removal by Filter and Final Clarifier (lb./sq. ft./day)	
			M.G.A.D.	5-Day B.O.D. (lb./sq. ft./day)	Observed	Computed[2]
River Falls, Wis.	8.0	0	18.2	0.855	0.611	0.630
	8.0	0	17.0	0.894	0.660	0.659
	8.0	0	16.8	0.843	0.635	0.620
Webster City, Iowa	7.5	0.05	20.4	0.462	0.290	0.335[6]
	7.5	0	10.3	0.100	0.055	0.072[6]
Austin, Minn.[3]	6.0	0	21.4	1.640[4]	0.713	0.685[7]
Owatonna, Minn., No. 1	7.0	0	18.8	0.995[5]	0.522	0.300
	7.0	0	18.5	0.604[5]	0.350	0.300
	7.0	0	18.2	0.562[5]	0.375	0.300
Owatonna, Minn., No. 2	6.0	0	15.9	0.845[5]	0.346	0.288
	6.0	0	15.3	0.500	0.240	0.288
	6.0	0	15.0	0.462	0.266	0.288
Englewood, N. J., No. 3	8.0	0	27.3	1.040	0.648	0.735
Englewood, N. J., No. 2	8.0	0	27.3	1.040	0.768	0.735

[1] All observed data except for Englewood, N. J., from study by Upper Mississippi Board of Engineers (1). Englewood, N. J., data by New Jersey Department of Health (5).

[2] Computed removals based on Figures 1 and 2, at hydraulic loading of 20 m.g.a.d. Observed removals are directly comparable only at this hydraulic loading; it is to be expected that observed removals are greater than the computed where loading is below 20 m.g.a.d., and less than the computed where loading is at higher rates.

[3] Average of three tests.

[4] Summer overload.

[5] Winter overload.

[6] Removal computed on basis of applied settled sewage, while actually flocculation preceded the filters.

[7] Computed on basis of maximum allowable load at maximum efficiency—1.0 lb. per sq. ft. per day—of which 68.5 per cent is removed by the 6-ft. bed, the remainder passing through.

Camp Callan the maximum extraction allowable for maximum bed storage in the 6-ft. filter is 0.538 lb. per sq. ft. at the mean temperature of 74.5° F. (23.6° C.). This extraction could be accomplished without recirculation at a maximum applied load of 0.538/0.685 = 0.785 lb. per sq. ft., or with *R/I* of 0.85 (extraction 76 per cent) at a maximum applied load of 0.538/0.76 = 0.708 lb. per sq. ft. Hence the bed is overloaded at an applied load of 0.80 lb. per sq. ft. at 23.6° C. If the temperature were above 26.3° C. the maximum extraction would be 0.606 lb. per sq. ft., and with an *R/I* of 0.85 and the applied load of 0.80 lb. per sq. ft. the bed storage would just come to equilibrium at the maximum allowable value for a 6-ft. bed.

Table III shows similar comparisons, in so far as data permit, based upon results reported for municipal sewage treatment plants. Referring to the computed values for plants Nos. 1 and 2 at Owatonna, Minn., the temperature was assumed at 10° C. and the removals computed on a maximum allowable loading of 0.42 lb. per sq. ft. per day for maximum efficiency. Winter B.O.D. overloading started on April 17, prior to which date the filters operated at a light loading. Consequently the beds at the time of test on April 20–23 were below equilibrium accumulation, with the result that part of the overload was accommodated by storage, producing temporary abnormal removals. It will be noted that

the observed and computed results approach closer agreement as the overload diminished.

Further data are needed to refine the constants involved in the basic theory. Studies are particularly needed of results at various hydraulic loadings to define the limiting B.O.D. loadings, and of results at intervals of bed depth to define k and L.

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SEWAGE TREATMENT FOR BOISE, IDAHO

A new sewage treatment plant for Boise, Idaho, on which bids are expected to be taken this summer, was described in detail at the 1948 Annual Meeting of the Pacific Northwest Sewage Works Association in a paper presented by L. R. Howson of the consulting engineering firm of Alvord, Burdick and Howson, Chicago.

Designed for a population of 57,000 and an average sewage flow of 12 m.g.d. (1960 conditions), the plant will provide complete treatment by the activated sludge process. Discharge will be to the Boise river, in which the flow is controlled artificially through the operation of the Arrow Rock dam upstream from Boise. This results in relatively high summer flows when water is released for irrigation purposes, and in relatively low flows during winter. The plant effluent will be chlorinated during the irrigation season.

The treatment works will comprise two comminutor units; a pumping station housing three 10-m.g.d. pumps (two driven by gas engines); mechanically cleaned grit chamber; three rectangular primary tanks; aeration tanks; two final settling tanks; three digesters; open sludge drying beds and a chlorination basin. Of the three aeration blowers, two will be driven by gas engines that will operate on digester gas.

The project is expected to cost about $1,375,000 with the *Engineering News-Record* construction cost index at 438. The bond issue under which the work will be financed was approved by a referendum in which the majority in favor of the project was ten to one.

HIGH-RATE FILTER PERFORMANCE *

By F. W. Mohlman

Director of Laboratories, Sanitary District of Chicago

It is unfortunate that the development of high-rate filters has been so competitive, because each company promoting a certain type of filter has been interested in giving publicity to results of operation that apparently show the superiority of the company's type of filter. Certain helpful developments have occurred, such as approximately continuous dosage, recirculation, use of coarser media, uniform volumetric dosage and continuous discharge of flocculated solids, but many of the curves, formulae and assumptions derived from filter operation actually rest upon a deficiency of the B.O.D. determination: namely, that the same 5-day B.O.D. result can be obtained whether or not there is nitrification of the applied ammonia nitrogen.

The writer makes no claim that it is necessary to oxidize the ammonia nitrogen, with reference to conditions of disposal, but from the standpoint of work done by the filter it makes a lot of difference whether the treated effluent is in the first or second stage of the B.O.D. curve, and filter volume giving low rates of application is necessary if one wants to accomplish complete treatment by a filter.

Early Investigations

The Sanitary District of Chicago became interested in high-rate filters in 1935 and Halvorson's filter in Minneapolis was visited, followed by the installation of an experimental 20-ft. filter in Chicago. Later a Jenks two-stage shallow filter was operated for about two years. The summarized results of operation of these filters are shown in Table I.

At rates of 28 m.g.a.d. the B.O.D. in the effluent was 31 to 44 p.p.m., corresponding to about 50 per cent reduction from the influent, and suspended matter in the settled effluent ran from 28 to 54 p.p.m. Later, the shallow recirculated filter, at a rate of 21 m.g.a.d., yielded an effluent containing 31 p.p.m. B.O.D. and 37 p.p.m. susp. solids, removing 1,347 lb. B.O.D. per acre-ft. and producing 3.6 p.p.m. nitrate plus nitrate nitrogen.

The best of these results, however, was far from satisfying the requirements of dilution imposed upon the District by the Supreme Court, so high-rate filters were abandoned in favor of activated sludge treatment, which produces effluents with only 8 to 15 p.p.m. B.O.D. and correspondingly low suspended solids.

As the years have passed, numerous contributions have been made by the promoters of high-rate filters, with all possible consideration of the favorable factors. It is quite evident that a renaissance has occurred in the theory of biological filtration as exemplified by trickling filters, namely, the principles of low-rate application of load by nearly continuous coverage of surface, "raindrop" application, uniform unloading of solids, thorough secondary settling, recirculation of all varieties, and improved dosing apparatus.

Recent Studies

Many investigations have also been made by disinterested parties, such as the Walton investigations sponsored by the state sanitary engineers of the

* Presented at the Twenty-First Annual Conference, Pennsylvania Sewage and Industrial Wastes Assn., State College, August 26, 1947.

TABLE I.—Sanitary District of Chicago High-Rate Filter Studies

Type Filter	Period of Operation	Rate (m.g.a.d.)	Recirculation (%)	Lb. B.O.D. Removed per Acre-Ft.	B.O.D. (p.p.m.)			Susp. Solids (p.p.m.)			Nitrate + Nitrate N (p.p.m.)
					Filter Inf.	Final	Efficiency (%)	Filter Inf.	Final	Efficiency (%)	
Deep	Year 1937	27.7	0	1,187	72	31.1	57	74	31	57	1.8
Shallow	Year 1937	28.7	217	1,079	73	44.3	39	74	54	27	1.9
Deep	Aug.–Dec., 1937	28.3	0	1,198	73	35.2	52	73	28	62	2.5
Shallow	Aug.–Dec., 1937	21.1	231	1,347	73	30.6	58	73	37	49	3.6

Upper Mississippi Basin, the summarized results reported by Dreier (THIS JOURNAL, July, 1946; *Water and Sewage Works*, Jan., 1947) and the report of the National Research Council on "Sewage Treatment at Military Installations" (THIS JOURNAL, Sept., 1946).

The trickling filter results in the latter report were re-arranged in Tables VIII, IX, X and XI of the concluding summary report compiled by the NRC Subcommittee on Sewage Treatment in Military Installations and published in the January, 1948 issue of THIS JOURNAL. The tables group the data for four classes of filters: (1) deep, with no recirculation, (2) deep, with recirculation, (3) shallow, with recirculation, and (4) two-stage. The plants are arranged in the order of filtration loads, and some nitrification results are shown. Reference is made to these tables in the following discussion.

Table VIII in the summary report (THIS JOURNAL, Jan., 1948, page 73) shows the first series. These filters were all about 6 ft. deep and in most cases the load was quite low. Thus they could be classified as standard-rate trickling filters.

At loadings up to 720 lb. per acre-ft., except for the Fort Sheridan filter, the filters plus secondary settling tanks removed 85 to 92 per cent of the applied B.O.D., and the overall removal varied from 91.5 to 95.0 per cent. Fort Sheridan gave anomalous results, showing poor removals probably because of excessive primary settling period, pooling, and high application rates resulting from excessive resting periods. Nozzles discharged only 4.5 minutes out of 25, giving a very high momentary rate.

Nitrification continued quite well up through the loading rate of 377 lb. B.O.D. per acre-ft., but fell off at 429 and especially at 720 lb. per acre-foot. The low degree of nitrification at Ft. Benjamin Harrison—only 1.5 p.p.m. nitrite plus nitrate nitrogen—appears questionable with the 429 lb. loading, since the ammonia N decreased from 21.1 p.p.m. in the influent to the filter to only 6.1 p.p.m. in the filter effluent. Since surely more than 1.5 p.p.m. of this loss was nitrified it may be concluded that nitrification was active up to 720 lb. loading of B.O.D. per acre-foot.

The second series of filters (Table IX, NRC summary report, THIS JOURNAL, Jan., 1948, page 74) shows results for eleven plants, with loadings from 245 to 5,750 lb. per acre-ft., and recirculation of from 24 to 358 per cent of the applied volume. Of the first four plants, Gordon was not very effective in removal of B.O.D. but removal of suspended solids was excellent. Leaving out this plant, the overall removal of B.O.D. was around 93 per cent, up to a loading of 1,170 lb. B.O.D. per acre-foot.

The next four plants were loaded up to 2,000 lb. per acre-ft. and gave decreasing removals and practically no nitrification. Forrest and Jackson, at 2,530 and 2,870 lb. loading, gave decreasing removals, but Callan, at the enormous loading of 5,750 lb., gave good removals. This was the prize camp in operation, possibly due to very good secondary settling, which reduced the B.O.D. from 118 p.p.m. in the filter effluent to 77 p.p.m. in the final effluent. Good flocculation and low overflow weir rates were probably responsible for the high removal. The camp was located in Southern California.

Table X in the NRC summary report (THIS JOURNAL, Jan., 1948, page 76) shows results for shallow filters, with high rates of recirculation. The first four plants, except Kearns, gave poor filter results due to excessive growths of fungus on the filters.

The other three plants gave high B.O.D. removals up to 2,320 lb. loading, but obviously with no nitrification. Kearns gave 11.3 p.p.m. nitrite plus nitrate N with 792 lb. loading, but with excessive recirculation far beyond the bonds of economy.

The last four plants gave poorer results, down to 58 per cent overall removal (first-stage) at Frances Warren, the most heavily loaded filter included in these studies. This was only the first stage, the final effluent from the second stage being reduced to 66 p.p.m., an overall removal of 84.8 per cent. Plant efficiency was reduced by return of a heavy supernatant liquor, and also because of the severe Wyoming winter weather.

Results for two-stage filters are given in Table XI of the NRC summary report (THIS JOURNAL, Jan., 1948, page 77). These results were all good at moderate loadings except Warren, which was somewhat inferior for reasons given above. With the very high loading of 5,280 lb., Camp Roberts gave quite inferior removals.

Discussion

The individual results in Tables VIII to XI of the NRC summary report have been summarized in various groups in Table II, with increasing loadings from 253 to 8,250 lb. per acre-foot. The first group, deep filters without recirculation, gave 93 per cent overall reduction and is characterized by high nitrification and low volumetric and organic loads applied.

TABLE II.—Summary of Trickling Filter Plant Operation

No. Plants	Group Designation	Range of B.O.D. Loading (lb./acre-ft.)	B.O.D. Efficiency, Filter and Sec. Settling (%)	Overall B.O.D. Reduction (%)	B.O.D. Remaining (%)
4	Deep, No Recirc.	253 to 429	86.9	92.2	7.3
4	Deep, Recirc.	245 to 1170	85.7	90.8	9.2
8	Two-Stage	192 to 930[1]	66.5[1]	90.2	9.8
4	Shallow, Recirc.	792 to 2320	81.8	88.1	11.9
4	Deep, Recirc.	1190 to 1950	78.7	87.5	12.5
3	Deep, No Recirc.	720 to 2130	75.7	82.8	17.2
3	Deep, Recirc.	2530 to 5750	70.3	78.3	21.7
4	Shallow, Recirc.	2370 to 8250	70.1	74.8	25.2

[1] Second stage.

Next, recirculation enables the loads to be increased to 1,170 lb. per acre-ft., and in general results improved as recirculation ratios increased. At Boca Raton a filter rate of 14.9 m.g.a.d. plus 358 per cent recirculation gave an effluent with only 16 p.p.m. B.O.D.

Recirculation thus improved considerably results from a deep filter at 1,170 lb. per acre-ft. application, but the rate of recirculation seems too high for such a dilute sewage.

Next, two-stage filters gave excellent results but most of the work was done in the first stage.

For higher loadings, up to around 2,000 lb. per acre-ft., shallow filters with considerable recirculation (from 280 to 1,050 per cent) were able to produce around 90 per cent overall reduction of B.O.D. and, at Kearns, considerable nitrate with the highest rate of recirculation.

A mathematical analysis by Dr. Thomas (THIS JOURNAL, Sept., 1946, page 975) indicates that an 800 per cent recirculation rate gives the maximum increase in capacity of high-rate filters.

Finally, at high rates of loading, from 2,370 to 8,250 lb. per acre-ft., results were quite inferior to those produced by a standard low-rate filter.

It is interesting to note that loadings above 2,000 lb. per acre-ft. resulted in effluents containing around 70 p.p.m. B. O. D., overall removals of 78 per cent, and no nitrification. This is far from the quality of an effluent from standard low-rate filter operation, even though the loading is less than the 3,000-lb. rate used in design of high-rate filters.

None of the filters loaded at over 2,000 lb. B.O.D. per acre-ft. produced nitrification. For the period during which nitrogen tests were made, some of the results are shown below:

Post	Lb. B.O.D. per Acre-Ft. per Day	Ammonia Nitrogen as N (p.p.m.)		Nitrite + Nitrate N (p.p.m.)
		Influent to Filter	Final Eff.	
Campbell	172	29.1	3.9	17.4
Fitzsimons G. H.	283	19.9	12.1	0.9
Benj. Harrison	199	21.1	6.3	1.5
Swift	197	27.4	9.7	11.8
Leonard Wood	256	44.2	9.2	19.5
Carson	320	14.3	8.0	2.0
Drew Field	974	25.1	18.2	0.9
Jackson	2930	29.0	20.4	0.8
Knox	1563	15.7	13.4	1.9
Bragg	3900	33.5	32.0	Tr.
Kearns AAF[3]	678	26.0	22.0	12.3
Gordon[2]	392	22.6	16.6	5.0
F. E. Warren[2]	980	46.1	21.9	7.0
Claiborne[1]	1040	32.0	24.0	1.2

[1] First-stage.
[2] Two-stage.
[3] Recirculation, 1,050 per cent.

It will be noted that the ammonia nitrogen shows very substantial reduction in the lightly loaded plants, with corresponding high nitrates in effluents. For single-stage plants, at loadings in excess of 974 lb., ammonia is reduced very little and there are no nitrates. Two-stage plants show nitrates.

Considerable oxidizing intensity is necessary to promote nitrification. The ammonia present requires 4 oxygen to 1 nitrogen, or 4.56 times the decrease in ammonia nitrogen. This can require considerable air in activated sludge treatment, or filter surfaces, for oxidation, and therefore the dosing rates must be low if nitrification is to occur.

It seems difficult to believe, therefore, that effluents from high-rate filters, dosed at rates higher than 1,000 lb. B.O.D. per acre-ft. per day, are just as completely treated as effluents from standard low-rate filters. There is a fallacy in using only the 5-day B.O.D. to measure the results accomplished.

For many conditions of disposal,

however, a nitrified effluent is unnecessary, and for such conditions, intermediate grade effluents will suffice, such as those from chemical treatment as well as from high-rate filters. For Army camps, urgent as well as temporary, such filters were highly satisfactory. Are they as satisfactory for permanent use in municipal installations?

HIGH-RATE FILTER PERFORMANCE—A DISCUSSION

By W. A. Hardenbergh

Editor, Public Works Magazine, New York City

The performance of high-rate trickling filters is a matter of record. Somewhat over a hundred such filters were built to serve military establishments during the war. On these, there are available the excellent data prepared by the National Research Council Sub-Committee on Sewage Treatment at Military Installations (1). Operation records on many of the high-rate filters used by municipalities and industries are also available, but these data are not generally so complete and authentic as those from the military establishments.

There are four types of high-rate filters. They are described, in the words of the manufacturers or their representatives, as follows:

"Biofilter (2) is a term applied to high-rate filters, normally comparatively shallow, which employ . . . the recirculation of all or part of the filter discharge back to the detention tank. The recirculated filter discharge may be filter effluent, or secondary clarifier contents, underflow or effluent."

Aero-Filters are "one classification of the 'high-rate' trickling filter group" having "a low momentary rate of sewage application whereby a high daily capacity for B.O.D. reduction is obtained." This process (3) "applies the sewage over the media in a very thin film. . . ." In the Aero-Filter recirculation is used at periods of low sewage flow in order to maintain a minimum necessary rate of application at which the distributor will function properly; it is also beneficial for treating strong wastes.

"The Accelo-Filter system (4) involves the direct recirculation of unsettled effluent from a biological filter back to the inlet of the filter distributor. This process may be used with either low-rate or high-rate filters."

"Reversible double filtration (5) consists of two trickling filters arranged to be operated for two-stage filtration with provision for reversing the sequence of the filters so that each may alternately serve as the primary and the secondary filter. This will allow the primary filter to be utilized with maximum effectiveness by applying, for short periods, loadings approaching the limit of the capacity of the filter. The secondary filter meanwhile will operate under much reduced loadings. . . ."

Loadings for high-rate filters are now quite well established in the range of 3 lb. of raw sewage B.O.D. per cubic yard of stone per day. With the reduction obtained by primary treatment, the applied B.O.D. is generally designed to be a little less than 2 lb. per cu. yd. or about 3,000 lb. per acre-foot. There is evidence, however, that heavier loadings are possible when recirculation is employed. In the experimental work done by the U. S. Public Health Service at Neosho, Mo., loadings in excess of 2.5 lb. of B.O.D. per cu. yd. were applied with no indication of a break from the straightline trend of removal. Banister and Ellison (6), using tile media for the treat-

ment of strong sewages containing milk, packing and canning wastes, report a normal loading of 3.3 lb. of B.O.D. per cu. yd. of media with a B.O.D. removal of 70 to 75 per cent; and nearly straightline removals up to 6 lb. or more per cubic yard. With stone media, they report a critical loading of about 4.5 lb. of B.O.D. per cu. yd., with removal consistently less than for tile.

Two of the plants noted in the NRC report were loaded considerably higher than the limits indicated above. Camp Callan, a deep filter employing recirculation, had an average applied loading of 5,750 lb. per acre-ft. or more than 3.5 lb. per cubic yard. Removal was 4,280 lb. per acre-ft., or 74.5 per cent. The Fort Bragg filter, a shallow unit, had an applied load of 4,340 lb. of B.O.D. per acre-ft., or about 2.7 lb. per cu. yd., and gave a removal of 80.7 per cent. Both of these plants employed recirculation. The Great Lakes plant, a deep filter without recirculation, had a loading of 2,130 lb. per acre-ft., or 1.3 lb. per cubic yard. Removal was 71 per cent.

Since B.O.D. removal is proportional to the load applied, a higher B.O.D. loading will always result in an effluent containing a higher concentration of B.O.D. This applies to any particular process, but by means of recirculation or two-stage treatment much better results can be obtained than with a single passage of the sewage through the filter. Single-stage high-rate filters without recirculation may accomplish a removal of 70 per cent of the applied B.O.D., or sometimes a little better. With an applied sewage of 200 p.p.m., this means an effluent with about 60 p.p.m. To obtain an effluent containing only 30 p.p.m. of B.O.D., with the relatively standard loading of 3,000 lb. per acre-ft., or 1.86 lb. per cu. yd., recirculation is necessary. According to Gloppen (3), in order to maintain an effluent of 30 p.p.m. B.O.D., the applied sewage should not exceed 135 p.p.m. B.O.D. Normally recirculation will be required to dilute the settled sewage to this strength.

Two-stage treatment will accomplish remarkable results, even with heavy loadings. Camp Roberts (1), with a loading of 8,680 lb. per acre-ft., or more than 5 lb. per cu. yd. of filter media, produced an effluent with an average strength of 53 p.p.m.; Fort Warren with a loading of 8,520 lb. per acre-ft. produced an effluent with 66 p.p.m; and Fort Sill, with a loading of 6,440 lb., or 4 lb. per cu. yd., had an effluent with 26 p.p.m. of B.O.D.

The 1-m.g.d. plant at Liberty, N. Y., a two-stage biofilter, was designed to handle a raw sewage loading of 3.1 lb. per cu. yd. of media. In July, 1944, the average flow was 1.29 m.g.d.; the average raw sewage B.O.D., based on composites from 8 A.M. to 2 P.M., was 520 p.p.m., representing a 24-hour composite of probably 360 to 370 p.p.m.; and the average effluent from the secondary clarifier (9 A.M. to 3 P.M. composite) contained 21 p.p.m. B.O.D. The actual effluent B.O.D. content during this month averaged slightly less than 6 p.p.m., the secondary clarifier effluent being passed through a magnetite filter and chlorinated before discharge into the stream. The results for 1944 are about the same as those that have been attained consistently ever since the plant was put into operation in the fall of 1940. Operation is by one man, which accounts for the daytime tests. During the winter, the plant is operated without recirculation as a conventional trickling filter, with satisfactory results, since the population load is then much lower, Liberty being a summer resort.

There is a need for more knowledge about the requirements for underdrainage and ventilation in filters. Certainly, adequate provision should be made to remove the liquid promptly

and to provide air to the bed, not only when the plant is new but also after it has been in service for many years and has accumulated a considerable organic growth. Those who have had the experience of removing the stone from an old filter will appreciate the amount of material that is found in them, especially in the bottom few inches through which the filtrate must pass and air must enter.

Pretreatment should be the best that can be provided. Anything that can be removed by settling results in that much less load on the secondary treatment units. The necessity for good design and adequate provision in final settling is just as great. It is well to remember that the clarifier following the filter is essentially a part of it, and must do its share in removing the settleable material in the filter effluent.

Media size and type for best treatment results have not been determined. A careful study of filter operating results does not give any conclusive basis for design. There is general agreement that the stone should not be too small, nor too large. Probably 2½- to 3½-in. or 3- to 4-in. represents good general practice and is desirable. The writer's preference would be for the larger stone, even in the secondary units of two-stage filters. Tile media have not been widely used, but should certainly be considered for strong sewages. According to Banister and Ellison (6), tile block is a "uniform material, permanent in character and self-cleaning. It will not pond. The normal design loading for a tile media high-rate filter is about 3.33 lb. per cu. yd. of media, permitting the use of a unit 10 per cent of the size of a low-rate filter. . . . The small size . . . permits economical housing, thus providing odor control, fly control and better treatment during the winter months." When a high degree of treatment is required and the final effluent must have a low B.O.D. content, these high-rate filters are followed by low-rate filters with stone media.

It is likely that two-stage filtration will become more general, with the use of high-rate filters as roughing filters carrying a very heavy load, and with final treatment by secondary high-rate filters, low-rate filters or activated sludge. All these methods are now in use, and with good results. The selection among them should be largely a matter of local conditions.

It appears reasonable to say, as regards high-rate filters, that a sound basis for design exists, but there is no explanation of the fact that some installations perform in a superior manner. It has been a matter of interest to the writer to investigate much of the data available to determine whether media size, underdrainage provisions, the character of the water as respects pH and alkalinity, and various other factors might have an important influence. None of these, with the possible exception of underdrainage and ventilation, appears to have any effect on the quality of the effluent from a trickling filter.

Perhaps it goes back to what F. H. Waring terms the "treatability of the sewage." That may be reflected in the B.O.D. characteristics of the sewage and the rate of biochemical oxidation. The NRC report brought out the varying values of k in military sewages. The average value of k for domestic sewage is 0.10, but the average value for the sewages at 16 military posts was 0.18. With k equal to 0.10, the 5-day B.O.D. represents 68 per cent of the ultimate B.O.D., but when k equals 0.18, the 5-day B.O.D. represents 87.4 per cent of the ultimate.

Thus, the B.O.D. test may be a varying rule for measuring operating characteristics, with naturally varying results. It seems unlikely, however, that this is the sole reason for the variations in performance noted at

different plants. Uniformity of loading and of sewage application is probably a factor of at least some importance. Study of the other factors in design or operation that so markedly influence operating results furnishes an enticing field for future research and investigation.

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SEWAGE OZONATION AT WEST KELSO, WASH.

Of considerable interest to those attending the 1948 Annual Meeting of the Pacific Northwest Sewage Works Association at Boise, Idaho, in May, was a report by a special committee of the association on the status of the sewage ozonation plant at West Kelso, Wash. The West Kelso ozonation installation was briefly described and discussed in the November, 1946, Journal (p. 1211).

Extracts from the committee report follow:

"The main structure and more important features of the plant were built during 1946. . . . Many changes have been made in the course of experimentation. Outwardly, to the casual visitor, these would hardly be noted except in the realization that many gadgets, bright stainless steel ducts, automatic contrivances, gages, and miscellaneous items of equipment have been added. These have been changed, added to, modified, and adjusted as a result of experiences in operation. Such work must have been very costly; the interior of the building seems crowded to the limit of its capacity to provide cover for the many items of equipment. . . . Outwardly, . . . the appearance of the building which houses the principal units of the plant is not unpleasing. Closer examination reveals some rather surprising architectural features which must be seen to be appreciated. The nominal capacity of the plant was required to be 200,000 g.p.d. of normal domestic sewage.

"Financial, structural, and operational difficulties apparently were felt by the end of 1946, or early in 1947. From the time of the meeting in Victoria (May, 1947) . . . until near the end of 1947 the plant was in a state of almost continuous experimental operation . . . tests to determine the results of these experimental operations by the authorized technical staff of the Department of Health have never been requested or made.

"In the early fall of last year "Amozone" requested the City of Kelso to finance further experimental operation. This was refused and the plant thereafter ceased operations even on an experimental basis.

"In December 1947 "Amozone" informed the city that the plant was completed, ready for operation and requested payment. This the city refused, whereupon, to the best of information available to the committee, the plant was locked up and has remained so to this date (May, 1948)."

The committee's main conclusion was that "For all practical purposes the West Kelso plant has not been successful and there appears to be no reasonable evidence that it ever will be acceptable on the basis of contract obligations."

THE CONTINUOUS-FLOW PRINCIPLE IN SEWAGE TREATMENT

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Technical advances have not always been achieved solely by observation, experiment, and engineering development; they have oftentimes arisen out of critical examination of an historical evolution. In the history of sewage treatment one may derive from the processes of earlier days a principle which may possibly lead to many new developments.

Reference is made here to the principle that, in this field, continuous-flow operation always yields better performance than any sort of intermittent process. There are five phases of sewage treatment in which historical developments have proved the truth of this principle:

1. The sedimentation process originated in the observation by chemists that a sample of sewage in a beaker deposits sludge and thereby becomes clarified. Applying this observation to municipal purification plants, engineers constructed the first settling basins in England for fill-and-draw operation. The basins were filled with sewage, which was allowed to settle for a predetermined number of hours and was then drawn off slowly, leaving the settled sludge behind. Not until later did the engineers conceive the idea of allowing the sewage to settle while flowing continuously through the basin, thereby eliminating both the time lost in filling and emptying the basin and the loss of head entailed in the fill-and-draw procedures. The laws of sedimentation in a continuous-flow basin are now well established. Even so, the celebrated Iddlesleigh Commission of England, whose reports still stand as the best textbooks in this field, treated fill-and-draw sedimentation as at least the equivalent of continuous-flow operation in their fifth report, published in 1908. Today, fill-and-draw operation of settling basins is practically unknown.

2. Biological contact beds have a similar history. They developed out of the experience with irrigation fields and sand filters in about 1893. Among the simultaneous developments were the contact beds of the engineer Santo Crimp and the chemist Dibdin, and the trickling filters of Corbett. The objective in each case was to improve on the performance obtained with undisturbed earth by placing coarse granular material in layers and thus increasing the air supply available to the working bacteria. Like the first settling basins, the contact bed was filled with sewage and was then emptied after a suitable contact time had elapsed. The trickling filter operated on a continuous flow. For nearly twenty years the profession did not recognize that the contact bed was wrong in principle and the trickling filter right. In early European practice, many more contact beds were built than trickling filters. Not until later did the trickling filter become established. Today, however, the contact bed is almost forgotten.

3. As stated above, the trickling filter differs from the contact bed in incorporating continuous-flow operation. The first filters had no interruption of flow, but the principle was in time forgotten. Engineers found that the spray nozzles and rotary sprinklers, which were used to distribute the sewage uniformly over the surface, operated at their best when receiving a heavy uniform flow. But municipal sewage does not provide such a flow. At night there is but little flow. During the day the quantity rises to a peak and then declines. On this account, various types of "interrupters" were introduced; these held back the flow until the distribution system could be provided with a full dosage. Finally there appeared, especially in America and England, large treatment plants in which the trickling filters at times lay idle for 20 to 60 minutes between heavy doses of sewage. It was a puzzle as to why such filters could be built in larger and larger sizes, and with ever-decreasing load factors, without any improvement in the quality of the effluent secured from them.

In 1934 the problem was attacked by Halvorsen, an American bacteriologist. He knew that the work of purification in biological filters was done by bacteria, and, as a bacteriologist, he knew also that bacteria must be fed from solutions. Hence the long pauses for aeration were so much lost time. He abolished them simply by bringing so much sewage to the filters that full flow was maintained at all times. By this means he increased the loading of the filter five- to ten-fold and found that the filters continued to perform without much decrease in the degree of purification secured. Thus continuous-flow operation made possible the "high-rate filters" which are distinguished by the fact that they remain free from sludge and also from flies because of their high surface loading and continuous flushing action. Here too, continuous-flow operation has proved superior.

4. If one wishes to determine whether a sludge or other organic sediment will decompose under anaerobic conditions, a digestion experiment can be carried on in a suitable chamber and methane formation noted. The next step is to place the sludge sample, together with an inoculum containing the necessary bacteria, in a bottle under controlled temperature conditions and measure the gases formed in a specified period. In such bottle experiments one does not obtain as much gas as is obtained from the same quantity of sludge at the same temperature and over the same period of time in a large purification plant, because the large plants are now operated only under continuous-flow conditions. Fresh sludge is added and digested sludge withdrawn in small quantities and at short intervals. Here too, the nutrient is brought continuously to the bacteria. It was precisely this which constituted one of the advantages that the "Emscher tanks" possessed over other digestion tanks for forty years. Even in experimental work, the ultimate gas production is only attained when continuous addition and withdrawal of sludge is practiced, as Buswell has shown.

5. The activated sludge process was developed in the form of bottle experiments by the American chemist Clark, in Boston in the year 1912. In his experiments, bottles equipped with aeration devices were filled with sewage at regular intervals, and subsequently emptied, in such a way—and this is the essential feature—that the sludge activated by the aeration always remained in the bottle and carried out the purification of the sewage added in the next cycle. The English chemist Fowler had seen these experiments in Boston. He confirmed them at Manchester and, with his co-work-

ers Ardern and Locket, developed the activated sludge process in its present form. Here again, the essential change was the substitution of the continuous-flow process for the troublesome fill-and-draw procedure, as in the examples cited previously. The engineers Jones and Atwood, who founded "Activated Sludge, Ltd.," were active in the development of the process. This company later instituted patent suits against those American cities which had built large purification plants of the activated sludge type. In the suit, it was to no avail that the cities claimed that the process was already known in America through the work of Clark. The courts recognized that the substitution by Fowler of a continuous-flow process for Clark's fill-and-draw procedure constituted a real and decided improvement.

Conclusion

These examples show that continuous-flow operation has in every instance proved itself superior to intermittent flow and that, in the history of sewage treatment, decades have often been lost by persisting in the use of intermittent processes. One can only advise investigators who concern themselves with the field of sewage treatment not to strike out on the detour of intermittent flow in future work, or even to fall back on it, but to strive constantly for the continuous-flow process. This idea apparently holds good in many other technical fields.

MAKE YOUR HOTEL RESERVATIONS FOR THE DETROIT CONVENTION

The Hotel Statler at Detroit, headquarters for the Twenty-First Annual Meeting of the Federation in October, will be able to accommodate most of the out-of-town registrants. Some rooms will also be made available by the Book-Cadillac Hotel, located about three blocks from the Statler.

Requests for room reservations should be addressed directly to the hotel. Note that the technical program will open on Monday morning, October 18, and will close at noon on Thursday, October 21.

WRITE NOW FOR YOUR RESERVATIONS!

ANALYTICAL PROCEDURES FOR THE DETERMINATION OF METALS AFFECTING SEWAGE TREATMENT *

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It is a well-recognized fact that certain metals have a deleterious effect on sewage treatment processes. Iron, copper, and zinc probably are the most injurious metals, while others, especially nickel and chromium, are definitely suspected of causing trouble. Since these metals are introduced into the sewage by metal-processing industries, especially steel plants and electroplating works, it may be well to consider not only the metals mentioned above, but also the accompanying metals—such as lead, cobalt, mercury, cadmium, tin, and possibly silver —as possible offenders. While it is not a metal, cyanide as used in the electroplating processes makes it necessary that this substance be considered also.

Metallic Waste Interference

Plant records show that metals have been a sewage plant problem for many years. The Fostoria, Ohio, sewage treatment plant stands out as one that has had an excessive amount of trouble. The *Fourth Annual Report* (1) of the Ohio Conference on Sewage Treatment (1930) gives a detailed account of the difficulties up to that time. Here the principal offender was iron, but the presence of copper was reported and quite possibly it, too, contributed to the damage. Rudgal (2) quotes the experiences at Kenosha, Wis., where copper in the sewage accumulated in the digesters and almost completely stopped sludge digestion. Oeming (3) mentions that copper, chromium, and zinc are notable offenders in inhibiting sludge digestion. He also mentions the effect of cyanides on fish life, but does not indicate any relationship between sludge digestion difficulties and the presence of the cyanides. The files in the office of the Engineering Division, Ohio Department of Health, indicate some of the difficulties other Ohio plants have encountered. J. R. Collier, at Elyria, reported that zinc has caused 70 per cent stoppage in the digesters. London, Ohio, reported similar difficulties, the digested sludge showing not only 535 p.p.m. zinc, but also 219 p.p.m. lead, 1.4 p.p.m. copper, 53 p.p.m. tin, and 1670 p.p.m. iron. This indicates a high concentration, as compared to what might be considered a normal sewage. For example, analysis was made in June, 1942, on the Columbus, Ohio, sewage and sludge, which yielded these data:

Metal	Sewage (p.p.m.)			Sludge (%)		
	Raw	Settled	Final	Raw	Digested	Dried
Copper	0.2	0.15	0.0	0.018	0.025	0.023
Zinc	5.0	4.0	0.0	0.40	0.42	0.33

The digestion was reported as being normal at the Columbus plant at that time.

* Presented at Twenty-First Annual meeting, Ohio Conference on Sewage Treatment, Columbus, Ohio, October 3, 1947.

At about the same time two sets of samples from Fostoria showed the following:

	May 11, 1942		Sept. 17, 1942	
	Cu	Zn	Cu	Zn
Raw sewage (p.p.m.)	2.4	20	8.8	56
Raw sludge (p.p.m.)	2.5	865	691	1934
Dry basis (%)	0.69	2.77	1.55	4.35
Digested sludge (p.p.m.)	845	401	978	8508
Dry basis (%)	0.96	4.55	1.14	9.89

Sludge digestion was reported as being stopped at Fostoria during this period. More recent reports from Fostoria show the presence of zinc, as well as copper, and large amounts of iron in the raw sewage and in the raw and digested (so-called) sludge.

Proposed Ohio Studies

Because of the difficulties reported and because of the anticipated difficulties at other Ohio sewage plants, the Division of Engineering, Ohio Department of Health, has asked the Laboratory Division to cooperate in an intensive study of this problem, and give special attention to the following cities in the state: Alliance, Bucyrus, Canton, Cleveland Southerly, Cleveland Westerly, Columbus, Dayton, Delaware, Elyria, Findlay, Fostoria, Lima, Mansfield, Springfield, Toledo, Troy, Wooster, and Tippecanoe City. Of the above list, Delaware and Columbus were proposed for control, since it is believed that there should not be an excessive amount of metals in these sewages. The rest of the cities have either reported troubles with metals, or have potential sources of this trouble. It was proposed to make analyses of the raw and settled sewage, the final effluent, the fresh and digested solids, and the digester supernatant. Analyses proposed were cyanides, copper, chromium, zinc, nickel, cadmium, tin, and mercury.

Because of the many unknown factors, it is believed that such a study is necessary in order to establish the tolerance of sewage for these metals, by comparison of the analytical results with the operating records furnished by the sewage treatment plants at these cities. Until the data on metal content are available there cannot be any real progress in this problem.

The Chemistry Section of the Division of Laboratories is wholly in accord with this program, but it has been limited in the amount of time and personnel available. It was felt that the regular work of the laboratory must be carried on, and no additional personnel has been made available, up to now, to assist in laboratory work on this program.

Present Analytical Methods Inadequate

Only those who actually have made analytical determination of the metals mentioned above can realize fully the tremendous amount of work and time required. Also, there is a surprising lack of information on analytical procedures for determining these metals in sewage and sewage sludge. It is sincerely hoped that this paper can arouse sufficient interest on the part of chemists for them to continue the investigations with a view toward improvement of present methods. The information presented in this paper is certainly not intended to be the final answer on the analytical procedures. It is intended rather that it should be a starting point for others to carry on this work in their own laboratories, so that more simplified procedures may be developed.

Methods of analysis for iron are fairly well known; various gravimetric, volumetric, and colorimetric methods are given in the literature, and will not be given a great amount of attention here. The other metals under discussion are usually present

in smaller amounts, however, and even if the quantity present is too small to determine except by colorimetric means, their determination is still important.

In the work done in the Division of Laboratories, various texts are used as reference, but most valuable was the one by E. B. Sandell, "Colorimetric Determination of Traces of Metals" (4). Other texts of more than casual interest are "Standard Methods for the Examination of Water and Sewage" (5), Scott's "Standard Methods of Chemical Analysis," Vol. 1 (6), Snell's "Colorimetric Methods of Analysis" (7), and Fiegl's "Spot Tests" (8).

Since no work has been done in this laboratory on tin, silver, or cobalt determination, these will not be discussed. Mercury, cadmium, and lead have received only a small amount of attention to date, so only casual reference to procedures will be made. Copper, zinc, chromium, nickel, and cyanides, being the substances for which more first hand data are available, will be discussed at greater length.

Gravimetric procedures are, for the most part, fairly well covered in the literature, and since the metals in question are seldom present in the sewages in sufficient amounts for accurate determination by this means, more attention is given to volumetric and colorimetric methods. In general, the policy has been to put all the metals in question into solution in concentrations sufficient for colorimetric determination or if possible, volumetric determination. Cyanides, of course, must be tested for in the original solution as soon as possible after sampling, so this test cannot be included in those made on the concentrated sample.

Cyanide

Cyanide is not considered a metal, but it goes hand in hand with the metals in the electroplating industry. Since it merits discussion, it will be discussed briefly at this point.

The method that is used for qualitatively testing for cyanides (9) briefly is as follows:

(A) *Reagents*

1. Phenophthalin (not phenolphthalein) solution; 1 per cent solution in approximately 0.67 per cent NaOH. This is not stable.

2. Copper sulfate; 0.01 per cent $CuSO_4 \cdot 5H_2O$ in water.

3. Phenolphthalin; $CuSO_4$ solution (0.5 ml. solution (1) in 99.5 ml. solution (2)).

4. Potassium hydroxide; 0.05 per cent KOH.

(B) *Procedure*

1. Place 1 ml. 0.05 per cent KOH solution in cell.

2. Add 2 ml. of sample.

3. Add 1 ml. phenolphthalin-copper sulfate solution, mix and compare.

4. If sample develops a pink color as compared to blank, cyanides are present. For quantitative determination compare with standards containing known amount of cyanide. (*Note:* Only one or two of the samples tested to date have shown cyanides, so little comment can be made on the comparison with standards. In every case, a small amount of cyanide solution—about 0.5 to 1.0 p.p.m.—is added to the sample and the test repeated to be certain there are no interfering substances. For low pH samples, more KOH solution may be required. Avoid excess KOH with water high in total solids.)

"Standard Methods" (5) describes a colorimetric method (page 90) using yellow ammonium sulfide and ferric chloride to form ferric thiocyanate. This method is stated to determine CN quantitatively from 0.1 to 4.0 p.p.m. using 50 ml. sample (after distillation).

Eldridge, in his book "Industrial Waste Treatment Practices" (10),

page 384, gives a method using acetone-sulfur reagent and ferric nitrate to produce the same color; also he describes the preparation of permanent standards from 0 to 5.0 p.p.m. CN, using platinum chloroplatinate and cobalt chloride.

Herda (11) describes a volumetric method, titrating with standard silver nitrate. By using various strengths of silver nitrate, ranges of over 50 p.p.m., 5 to 50 p.p.m., and less than 5 p.p.m. are said to be covered.

Sample Preparation

The cyanide tests are made on the premise that the cyanide radical either is soluble or is in a form that it will react with the reagents used. It is believed, however, that this is not true for the metals, because of the amount of insoluble material generally present in sewage (and sewage sludges).

It has been the practice to evaporate as large a quantity of sewage as is available after removing the portions used for the other analyses (usually 500 to 1000 ml. of sample is left); taking it to dryness, and igniting at about 500° C. Ignition temperature is purposely kept low to avoid volatilization of the metals, especially iron, tin, and mercury. The residue is taken up with HCl or, if solution takes place too slowly, with HCl plus HNO_3, and again takes to dryness. Sufficient HCl is then added to dissolve the metals and the insoluble silica is filtered off and the filtrate made up to a small volume, usually 10 to 25 per cent of the original volume of sample.

Sewage sludges, after ignition, also at low temperature, are dissolved in HCl or HCl plus HNO_3, taken to dryness, then taken up in HCl and the silica filtered off. The filtrates are made up to some known volume, so as to represent about a 1 to 3 per cent solution, based on the weight of the ashed sample. The final solution is adjusted to 0.1 to 0.2 N with HCl, generally by measuring the HCl used to take up the residual.

An aliquot, usually 25 or 50 per cent of the acid filtrate, usually is withdrawn and the iron removed by precipitation with excess NH_4OH. To avoid carrying down other metals the precipitate is dissolved in HCl and re-precipitated with NH_4OH and again filtered. The combined filtrates are concentrated and brought to their original volume (i.e., the volume of the aliquot taken), and set aside.

Analyses are made on the original filtrate for iron, nickel, chromium, and mercury. Tin, if determined, would be tested for in this portion. The iron-free portion generally is used for copper, zinc, and cadmium, but if the iron is low, these metals may be determined in the original acid solution and the iron removal procedure then could be omitted.

The method of sample preparation just described assumes that all these metals are kept intact on ashing, and that all are soluble. Also it is assumed that negligible amounts of the other metals are removed with the iron. No claim is made that this is true; in fact, appreciable co-precipitation probably takes place in certain cases. This factor should be investigated very carefully whenever time permits.

Types of Analyses

The analyses made on the solutions just described may be gravimetric, volumetric, or colorimetric. However, experience to date generally has been on samples containing insufficient quantities of metals for gravimetric work—in most cases too low for volumetric determinations—so that colorimetric determinations are made, using organic reagents.

Nickel analysis usually is made with dimethyl glyoxime, chromium with diphenyl carbazide, and the other analyses with diphenylthiocarbazone, or as it is generally called, dithizone.

Copper frequently is determined using sodium diethyl dithiocarbamate.

The reagents, especially dithizone, may contain impurities which must be removed. Sandell (4) describes this purification on page 89. However, the freshly purchased dithizone reagent (Eastman No. 3092) usually is pure enough to use without preliminary treatment.

Incidentally, colorimetric determinations are much simplified if access is had to a spectrophotometer or similar instrument. While it is possible to make visual comparison, instruments are of considerable aid. A colorimeter of the abridged spectrophotometric type with the necessary filters is quite useful, but a spectrophotometer of the Beckman or Coleman type seems to be the most satisfactory. The work being described was done with a Coleman No. 11 Universal Spectrophotometer, which may be adjusted to furnish light of any wave length from 350 to 800 μ.

The best instrument available is worthless, however, unless every effort is made to use only the best possible reagents. In dealing with the very small quantities of metals it is quite possible to introduce more of the ions in question by means of inferior reagents and poor distilled water than were originally present in the sample aliquot. The distilled water used for preparation of reagents and dilution of sample should be re-distilled in Pyrex, unless it is of very good quality. Some reagents must have interfering substances removed, i.e., with dithizone, before use.

No iron-clad rules can be set up for any one determination, because of the interference due to other ions in the sample. Since each sample may contain different metals or the same metals in greatly different amounts, the procedure for one sample may prove to be unsatisfactory for the next sample. It may be necessary to set up at least a half-dozen modifications of each procedure to eliminate interferences due either to other metals or a too high concentration of a metal that otherwise would not interfere. It has been the practice, when time permitted, to recheck or use an alternate method (if available) until a reasonable check was obtained.

Iron

For large amounts of iron, gravimetric determination by precipitation with ammonia, after buffering with ammonium chloride, may be used if other metals are present in small amounts. In this case the precipitate is ignited and weighed as Fe_2O_3.

The precipitation of iron by the reagent "cupferron" in acid solution as described in Scott (6), page 468, seems to be fairly satisfactory. The principal interfering substance is copper, which is dissolved by cold dilute ammonia. It is advised that the instructions in the reference be followed very carefully.

Sufficient aliquot should be taken to contain 50 to 500 mg. Fe. For smaller amounts of iron the standard colorimetric method using KCNS is recommended. This can be used for ferric iron as well as total iron, and ferrous iron then obtained by difference. Or ferrous iron may be determined directly by titration with $KMnO_4$. This latter method is described by Scott (6) on page 474. The writer has previously used the orthophenanthrolene method with decided success (see "Standard Methods," page 52), but has not applied it to industrial waste analyses.

Copper

For determination of copper in small amounts, two colorimetric methods described by Sandell (4) are both to be recommended, with the carbamate method (page 221) apparently a little more satisfactory. This method briefly is as follows:

1. Take aliquot containing 5 to 20 γ of Cu.*
2. Add 5 ml. of 20 per cent ammonium citrate.
3. Add two drops thymol blue indicator and adjust pH to 9.0 to 9.2 with NH_4OH.
4. Add 1 ml. of 0.1 per cent sodium diethyl dithiocarbamate and 5.0 ml. of CCl_4.

Shake 2 minutes.

5. Compare with standards containing known amounts of copper, or read in spectrophotometer at 440 μ and refer to curve obtained by readings of the standards. It is best to prepare standards of 0, 5, 10, 15, and 20 γ Cu each time and plot the curve.

It is to be noted that iron in amounts over 5 mg. and manganese over 0.5 mg. interfere. Nickel also interferes but can be removed by dimethyl gloxime. Copper can be determined by the dithizone method (Sandell, page 220), but bismuth, mercury, and silver are said to interfere. This procedure is:

1. Take aliquot containing 10 γ or less of Cu.
2. Make solution 0.05 to 0.1 N with HCl.
3. Shake for 2 minutes with 5.0 ml. of 0.001 per cent dithizone (in CCl_4).
4. Compare organic layer in spectrophotometer at 510 μ with standards having same acidity and same original volume. Both the above methods will work in the presence of small amounts of iron, but the dithizone method is more easily affected by iron, hence it is better to remove this interference.

If copper is present in larger amounts, a modified volumetric procedure may be used, i.e., titration with a standard copper solution. This method (Scott, page 377) is briefly:

1. Take aliquot (iron-free) containing 50 to 500 γ of Cu.
2. Boil off ammonia, cool.
3. Add 5 to 20 drops of 4 per cent $K_4Fe(CN)_6$ to a 100-ml. Nessler tube for sample, also to a second one for the blank.
4. Add 5 ml. of 10 per cent NH_4NO_3 to each tube, pour sample into one tube and bring both to 100 ml. with distilled water.
5. Add standard Cu solution (0.1 mg./1 ml.) to blank until color compares with that of sample.
6. If sample is cloudy before comparison, add very dilute lead solution to blank to simulate turbidity.

Zinc

Zinc is one of the most difficult metals to determine. The mixed color method with dithizone (Sandell, page 451) seems to be fairly simple, but the results with this method have not been too successful. The method most generally used is the monocolor method. Iron in large amounts must be removed in order for this procedure to be satisfactory. This method is described by Sandell (4), page 453, but it will be outlined briefly here (including slight modification):

(1) Take aliquot to contain about 5 to 10 γ of Zn.

(2) Evaporate to dryness, take up in 10 to 20 ml. of 0.1 N HCl.

(3) Add 0.5 N sodium acetate, in volume equal to 0.1 N acid.

(4) Add 600 mg. $Na_2S_2O_3$ (from 50 per cent soln.) for each mg. Cu in aliquot. (See text for amounts needed for mercury and lead.)

(5) Shake with successive 2 to 3 ml. portions of dithizone in CCl_4 until last portion is unchanged. Collect portions in second separatory funnel.

(6) Wash aqueous layer with 1 ml. CCl_4; add this CCl_4 to dithizone extracts.

(7) Wash CCl_4 extracts 2 or 3 times with 5-ml. portions of sodium thiosulfate-sodium acetate solution (see text for preparation and purification of solution). Then wash once with water.

* $\gamma = 1/1{,}000{,}000$ gram; γ/ml. = p.p.m.

(8) Remove excess dithizone with 0.04 per cent sodium sulfide wash solution, using successive portions until last portion is almost colorless.

(9) Remove CCl_4 layer, and bring to volume (say, 15 ml.) with pure CCl_4 and compare at 535 μ.

This method is not nearly as simple as it sounds, especially step (8). It has been found necessary to shake violently, allowing the mixture to stand for awhile, then to shake again before yellow color appears in water layer. Even this does not always work and more Na_2S solution may be needed. Frequently a stronger, say, 0.1 per cent, solution may be necessary.

This method requires very pure reagents, and it is almost mandatory that the text be followed explicitly in this regard. If extreme care is not used the standards (which by the way, are run each time) may show very little graduation of color. The standards prepared range from 0 to 15 γ of Zn. If the aliquot taken contains over 10 to 15 γ of zinc, an excessive amount of dithizone reagent is required to remove all of it. It is better to start with a smaller aliquot if over three or four portions of reagent are needed in step (5).

It is hoped that someone can suggest an easier method for zinc analysis; the one described above is felt to be too complicated and generally unsatisfactory. To date no work has been done on separation of interfering substance with H_2S, so that gravimetric or volumetric methods could be applied. However, this is probably one of the next steps to be taken, unless some better colorimetric method is found.

Chromium

Chromium is not especially difficult, although it is not exactly a fool-proof determination. The colorimetric test with diphenylcarbazide is used, and the technique given by Sandell (4), page 195, has been more satisfactory than that in "Standard Methods" (5), page 55. The procedure used is:

1. Take aliquot (Fe may be present) to contain 0.2 to 10 γ Cr.
2. Add NaOH pellets to make definitely alkaline.
3. Add 1 ml. 30 per cent H_2O_2 and heat to boiling.
4. Cool, add 6N H_2SO_4 to phenolphthalein end-point, add 0.83 ml. more 6N H_2SO_4 (this should be purified with $KMnO_4$, see text).
5. Filter if necessary and bring to about 20 ml.
6. Add 1 ml. of freshly prepared diphenylcarbazide reagent (0.25 per cent in 1 to 1 acetone).
7. Bring to 25 ml. in graduate or volumetric flask, mix and compare at 540 μ.
8. Standards should be prepared in same manner, starting with 0.2 N H_2SO_4 solution.

Larger amounts of chromate may be determined colorimetrically as the yellow CrO_4 radical by comparison with standards (Sandell (4), page 190).

Nickel

Nickel determination can be made for small amounts colorimetrically or for larger amounts by gravimetric methods, using dimethylglyoxime in either case. The colorimetric method below has been adapted from Sandell (4), page 342:

(1) Take aliquot containing 5 γ or more of nickel, adjust to slightly acid and bring to about 10 to 20 ml.

(2) Add 5 ml. of 10 per cent sodium citrate, and make alkaline with ammonia, adding a few drops in excess.

(3) Add 2 ml. (or more) of dimethylglyoxime (1 per cent in alcohol).

(4) Extract three times with 2 or 3 ml. of chloroform, shaking ½ min. each time.

(5) Shake combined chloroform extracts with 5 ml. of 1 to 50 ammonia, and withdraw chloroform.

(6) Shake water layer with 1 to 2 ml. chloroform and combine with chloroform extracts.

(7) Shake chloroform with 2 to 5 ml. portions of 0.5 N HCl.

(8) Combine acid solutions; use all or aliquot for nickel (bring to at least 10 ml.).

(9) Add 5 drops bromine water, then add concentrated ammonia to destroy color, plus 3 or 4 drops in excess.

(10) Add 0.5 ml. dimethylglyoxime solution, and bring to volume with H_2O.

(11) Prepare standards, having same original acidity as sample.

(12) Compare within 15 min. at about 525 μ.

This above method is to be used in the presence of copper. In absence of interfering amounts of copper and excessive amounts of iron, the following shorter procedure may be used:

(1) Take aliquot containing up to 20 γ Ni (dilute to less than 5 γ/ml.).

(2) Add 5 drops bromine water.

(3) Add 5 ml. 10 per cent sodium citrate.

(4) Add NH_4OH until bromine color is destroyed, plus 3 to 4 drops excess.

(5) Add 1 ml. 1 per cent (in alcohol) dimethylglyoxime.

(6) Bring to volume and compare with standards prepared in same manner.

Other Metals

For cadmium determination, the dithizone method given by Sandell (4), page 171, seems to be the most promising.

Tin determination apparently is subject to interference by many other substances. The dithiol method or phosphomolybdic acid procedure, as described by Sandell (4), pages 416 and 417, should be given consideration. Also, dithizone reagent may be used for lead (Sandell, page 285) and mercury (Sandell, page 321). There is considerable information in the literature on lead and mercury analyses, but since these two metals are not commonly encountered in industrial wastes, very little work has been done on them in this investigation.

Because sewage sludges usually contain larger amounts of the metals discussed, it is worthwhile to give some attention to gravimetric procedures for them. Since colorimetric methods were most applicable to sewages, however, it has been endeavored to make these methods apply to sludges as well. In view of the inherent difficulties and interferences in colorimetric work it may well be that the efforts should be aimed in the other direction, i.e., use gravimetric methods on those that contain sufficient quantities of the metals, and use the colorimetric methods as a last resort.

Conclusion

In conclusion, it should be remembered that this work has only been started; there is much more to be done to simplify the procedures before these analyses can be considered commonplace. It is hoped that the way can be opened to work out a comprehensive and cooperative program in this regard in order first to establish methods that are practically foolproof, and secondly to follow through in making these analyses routine, at least in many sewage treatment plants.

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TRANSCRIBED DISCUSSION

Dr. W. C. Weast, Case Institute of Technology, Cleveland, Ohio

Reference was made in Mr. Riehl's paper to the possibility that nickel is a metal which might be toxic to bacteria during sludge digestion. Recent work at Case has been carried out to establish toxicity limits of nickel in domestic sewage.

Nickel as nickel sulfate was added to raw sewage in concentrations from 1 to 2,000 p.p.m. Concentrations of nickel under 500 p.p.m. had no effect on digestion. With nickel concentrations of 1,000 p.p.m. digestion decreased 35 per cent. When the nickel concentration was increased to 2,000 p.p.m. digestion decreased 95 per cent.

If the nickel was added as nickel ammonium sulfate, digestion was increased as much as 10 to 30 per cent. The greatest increase of digestion occurred at the maximum nickel concentration used for this series, which was 133 p.p.m. The tests using higher concentrations of nickel as nickel ammonium sulfate have not yet been made. This increase of sludge digestion in presence of ammonium salts is in accordance with some recent studies of Dr. A. M. Buswell of the Illinois State Water Survey.

A very complete review of cyanide determinations is presented in an article published by T. R. Haseltine in the May, 1947, issue of *Water and Sewage Works*. This article describes the limitations of the analytical methods for cyanides under a variety of conditions. However, one excellent method not discussed either by Mr. Riehl or by Mr. Haseltine is the use of the polarograph for accurate determination of the cyanide content of a solution.

In regard to copper analysis, it is noticed that Mr. Riehl discusses the method of dry ashing the sample at 500° C. Our experience has been that low results are obtained by this method. Better results have been obtained by using perchloric acid to wet ash the sample.

Dr. L. Kermit Herndon, Ohio State University, Columbus, Ohio

As one goes into this work, he finds that established procedures require modifications for specific application. It must be realized that interpretations are always qualified by the type of sampling provided, and that analytical methods may not have given a complete story.

With reference to cyanide determinations it should be noted that samples containing sufficient alkalinity will not deteriorate rapidly. We have used the tartaric acid-distillation method with fairly good results. In this case,

½ grain of tartaric acid is added in excess of the amount required to neutralize the sample, and then it is distilled. The first portion of the distillate will contain the cyanide. Sulfides in the original sample will cause difficulty. A small amount of lead nitrate must be added to overcome it. Ninety-five per cent of the cyanide is in the first 5 per cent of the steam that comes over, so that a very good condenser system is needed to get all of the material condensed at the time. Other materials such as aqueous solutions of the halogens and ferricyanide will oxidize or affect the phenophthalein reagent. Chromates, nitric acid, ferric chloride, and halogen salts do not interfere. In the distillation procedure, the tartaric acid will decompose ferrocyanide to give high values.

Suggestions are offered for some of the other procedures. For example, in the copper determination, add a small quantity of sodium sulfate to clarify the solution after extraction. Ferrous iron interferes with this test.

Mr. Riehl is correct in stating the difficulties encountered in the analysis of small quantities of zinc. The laborious removal of dithizone in this step 8 may be done, instead, by pouring small quantities of chloroform through the aqueous liquid without shaking. If this is not successful, Mr. Riehl's step 8 is required. Cadium, nickel, and cobalt interfere with the method.

These procedures will become more important as time goes on, and it is necessary to simplify them. Most of them at the present time are in the status of being research procedures where the ordinary laboratory man cannot possibly hope to carry them out in the laboratory along with his usual routine operations. Routine tests are badly needed, and it would be a good policy to start now on a series of cooperative studies to develop short methods that may be used in the control laboratory. Mr. Riehl is to be commended for bringing together the existing, more or less standard procedures, and outlining their importance in the field of waste treatment.

Prof. George E. Barnes, Case Institute of Technology, Cleveland, Ohio

In order to emphasize the urgency for developing suitable test procedures the author mentions the toxic effect of several metals. Some comments may be in order.

Chromium has been very definitely reported as extremely toxic to sludge digestion, to fish life in the streams, and to biochemical processes such as activated sludge. It is not merely "suspect"; it is viciously toxic.

On the other hand, nickel is given by the author as being quite toxic; as a matter of fact, considerable research has indicated that nickel is only mildly toxic and then only in considerable concentration. The term toxicity is a relative one, and chromium, copper, and nickel are (weight for weight, or concentration for concentration) toxic about in the order named, rather than in the order suggested by the author. There is no accepted measure of relative toxicity, but a committee of the Federation is now working to develop an acceptable standardized procedure for determining this factor.

The speaker compliments Mr. Riehl on his compilation of the best available analytical procedures for determining these various substances, which are becoming increasingly important in sanitation, as applied particularly to trade waste treatment. In general, such tests have been developed for other than sanitary engineering purposes by metallurgical or process chemists who customarily think in terms of percentages and tonnages rather than in parts per million and gammas. Further, the tests may not

be satisfactory with certain interfering substances found in sanitary engineering practice. Again, they may be too complex or lengthy. Appraising existing procedures is a good forward step in developing new ones which are needed to an increasing extent.

Walter E. Malone, National Cash Register Co., Dayton, Ohio

As a representative of industry, the speaker is more concerned with the determination of metallic pollutants in storm sewer discharges than in sanitary sewage. Considerable time has been spent in our laboratory on an investigation of metallic impurities in the wastes discharged from our plant in Dayton to a storm sewer that empties into the Miami River. We are vitally interested in Mr. Riehl's compilation of analytical procedures for the measurement of trace constituents in wastes such as we produce.

As far as the determination of cyanide is concerned, we have covered fairly well all of the methods referred to by Mr. Riehl, and were not too successful in applying them to our particular case. We do have a method which has been found satisfactory for the determination of cyanides in concentrations down to 0.5 p.p.m. CN.

The procedure is as follows: Measure 100 ml. of sample into a 250-ml. beaker, and add three drops of 10 per cent caustic and 1 ml. of ammonium polysulfide. Evaporate to dryness, being careful not to overheat. Cool and dissolve the residue in a few milliliters of water. Add 3 ml. of 10 per cent cadmium chloride and 2 ml. of 1N H_2SO_4. Filter and wash, keeping the volume as small as possible. Add seven drops of 10 per cent ferric chloride solution and let stand for 30 minutes. Measure the per cent transmittancy (by photometer) with a blue filter.

There has been considerable difficulty in our laboratory in the determination of zinc and copper, and resort to modern spectrographic methods has been necessary. Excellent results in both zinc and copper determination have been obtained with the use of spectographic equipment.

Further study is needed on standard analytical procedures for metallic wastes and on limits of metallic pollutants in their effects on sewage treatment plants and streams.

MAKE YOUR HOTEL RESERVATIONS FOR THE DETROIT CONVENTION

The Hotel Statler at Detroit, headquarters for the Twenty-First Annual Meeting of the Federation in October, will be able to accommodate most of the out-of-town registrants. Some rooms will also be made available by the Book-Cadillac Hotel, located about three blocks from the Statler.

Requests for room reservations should be addressed directly to the hotel. Note that the technical program will open on Monday morning, October 18, and will close at noon on Thursday, October 21.

WRITE NOW FOR YOUR RESERVATIONS!

MEASUREMENT AND CONTROL OF SEWAGE TREATMENT PROCESS EFFICIENCY BY OXIDATION-REDUCTION POTENTIAL *

By John W. Hood

Superintendent of Sewage Treatment, Ridgewood, N. J.

All sewage treatment plant operators are familiar with the colorimetric method for the determination of pH. The test is widely applied in the practical control of treatment processes, even when the user may not be familiar with the theoretical and mathematical considerations upon which the measurement of pH is predicated.

In like manner, the determination of oxidation-reduction potential may be employed profitably and conveniently in connection with the survey, design, and control of operation of waste treatment works. Before demonstrating these applications, however, it is desirable to define oxidation-reduction potential (hereafter referred to as "O-R" potential), and to consider its general significance in the biochemical processes presently employed in the treatment of sewage and industrial wastes.

O-R Potential Defined

O-R potential is defined as the electrical pressure existing in a liquid as a result of the respective concentrations of oxidant and reductant present. As used here, the term "oxidant" embraces the forces present which increase the proportion of oxygen or acid-forming elements, or radicals, in the compounds contained in the liquid; the term "reductant" represents the forces present which increase the proportion of hydrogen or base-forming elements.

Hewitt (1) states that "Oxidation-reduction systems play so intimate and so essential a part in living organisms, that life itself might be defined as a continuous oxidation-reduction reaction . . . to gain a general view of oxidation-reduction processes, it is necessary to consider the electronic concept of atomic constitution."

Waksman (2) states: "Oxidation-reduction processes have commonly been interpreted in terms of oxygen; oxidation designated a process whereby oxygen was added to a substance or hydrogen was removed; reduction was applied to reactions involving the removal of oxygen or addition of hydrogen. However, in certain processes of oxidation-reduction no oxygen or hydrogen participates, as in the following reaction:

$$FeCl_2 + Cl \rightleftharpoons FeCl_3.$$

"Clark and associates (3) were therefore led to consider these processes in the light of addition or withdrawal of electrons. Taking the oxidation and reduction of iron, the following reaction may be given:

$$2Fe^{+++} + H_2 \rightleftharpoons 2Fe^{++} + 2H^+$$
$$2Fe^{+++} + 2O \rightleftharpoons 2Fe^{++} + O_2$$
$$Fe^{+++} + e \rightleftharpoons Fe^{++}.$$

"When the reaction proceeds from left to right, reduction is taking place; when it proceeds from right to left, oxidation is taking place. In the pres-

* Presented at Twenty-First Annual Meeting, Pennsylvania Sewage Works Assn., State College, Pa., August 27, 1947.

ence of methylene blue, nitrate, or other substances capable of acting as hydrogen acceptors, oxidation may take place even in the absence of atmospheric oxygen; this enables certain bacteria to live anaerobically. Processes of oxidation can thus be considered either as (a) aerobic processes, in which atmospheric oxygen acts as a hydrogen acceptor, or the oxidizing agent; and (b) anaerobic processes, in which organic or inorganic compounds act as the hydrogen acceptors, both processes resulting in the liberation of energy . . . the oxidation-reduction character of bacteriological media exerts an important influence on the growth and behavior of the organisms toward atmospheric oxygen. A knowledge of the oxidation-reduction potential of the media is important, not only in obtaining the optimum growth of an organism, but also for the purpose of using the medium for counting the organisms. . . . The lengthened lag phase of growth represents the time necessary for an organism to change the potential of the medium to a more favorable condition."

Re-examining the above reactions, it is possible to trace the migrations of valence electrons of the atoms (so-called because they are gained, lost or shared in chemical reactions) and to note that as a result, molecular hydrogen becomes hydrogen ions and atomic oxygen becomes molecular oxygen in a reduction reaction, and that the opposite occurs in an oxidation reaction. The third reaction depicts the role of the "free" electrons, in "reducing" ferric to ferrous iron. All three reactions illustrate the concept of the basically electrical nature of things.

Hewitt (4) states: "Oxidation and reduction processes are defined in terms of electron migrations; oxidizing properties are due to a tendency to part with electrons, and reducing properties to a tendency to take up electrons. When one substance is oxidized (parts with electrons) another is always simultaneously reduced (takes up the electrons liberated). This electronic concept has suggested a method of studying quantitatively, these reversible oxidation-reduction processes which are of vital importance to the living cell. The method is the measurement of electrode potentials, which enable the degree of oxidation or reduction of a system to be gauged and which render possible the grading of oxidizing and reducing systems according to their intensity levels.

"In a reversible oxidation-reduction system, the electrode potential depends upon the relative amounts present in the oxidized and reduced forms of the substance studied. If a solution contains a mixture of the oxidized and reduced forms X_o and X_r, the reactants in the reversible oxidation-reduction system are as follows:

$$X_r \rightleftharpoons X_o + n \text{ electrons}$$

then the electrode potential (E_h) at 30° C. will be given by the equation:

$$E_h = E_0 + \frac{0.06}{n} \log \frac{X_o}{X_r}$$

where E_h denotes potentials referred or corrected to the normal hydrogen half-cell or the potential difference at the 'normal hydrogen electrode'; E_o is constant for the system; X_o and X_r are the respective concentrations of oxidant and reductant.

"It follows from this equation, that the more oxidizing a system is, the higher (more positive) will be the electrode potential; more reducing systems will have lower (or more negative) potentials. . . . Hydrogen-ion concentration has definite effects on electrode potentials, so that strictly speaking, potentials can only be compared directly with others at the same pH."

It remained for Rohlich (5) to reduce these findings to sewage treat-

ment practice by their application to the activated sludge plant process at Madison, Wis., and to the related laboratory studies simultaneously undertaken.

Instrumentation

The quantitative study of reversible oxidation-reduction processes such as are encountered in sewage treatment is therefore made possible by measurement of differences in electrical potential. Unfortunately, colorimetric methods similar to those employed in pH determination have not, for a number of reasons, proved satisfactory. Consequently, electrometric methods have proved more acceptable. Since many plants are now employing the electrometric method of pH determination, there is in such cases a minimum of additional equipment and expense involved in adapting the potentiometer to O-R potential measurements.

For pH work, a standard vacuum tube potentiometer, glass electrode and saturated KCl calomel cell, or reference electrode, are generally used. For O-R potential, the glass electrode is replaced with an unattackable electrode of a "noble" metal, usually platinum. An unattackable electrode is one, which when immersed in the system (sample), will not participate therein, but will act merely as an inert but efficient conductor of electrons to or from the system when the circuit is so adjusted.

Recent verbal advice would seem to indicate that the old traditional platinum electrode may be replaced by an improved type electrode, one reason advanced being that the platinum electrode yields values which are erroneously high. This is of vital importance in connection with the interpretation of values, and conclusive information will be welcomed.

The potentiometer may be equipped with a dial calibrated in pH units and volts. It is usually battery-operated and, since the case is sturdy and both O-R potential electrodes are of rugged construction, the entire assembly is portable. Some care is required to keep this equipment in satisfactory service for an indefinite period. Life of batteries may be extended beyond a year, even with daily usage, provided the switch is turned off when work is completed. Before and after each O-R potential determination the platinum electrode must be thoroughly cleaned by immersion in nitric acid, followed by rinsing with distilled water. When work is completed the saturated KCl calomel cell salt bridge should be expelled and replaced with distilled water.

O-R Potential Systems

Sewage treatment plants usually embody two basic processes: aerobic for the liquid (oxidation) and anaerobic for the solids (reduction). There are many gradations and frequently contradictions within each plant, which can be detected by O-R potential survey. For example, the aerobic units should yield ascending positive numerical O-R potential values from influent to effluent. The writer has found that O-R potential readings at anaerobic units should be from -100 to -200 millivolts for maximum efficiency.

Trickling filters, slow sand filters, and activated sludge plants are capable of varying degrees of treatment in terms of O-R potential. For example, activated sludge and sand filters, under optimum conditions, are capable of performing the most complete treatment, reflected in high positive O-R potential effluent values, together with high relative stability. On the other hand, heavily loaded high-rate filters usually produce effluents of low stability that are poorly poised in O-R potential.

Eliassen (6) evaluates effluent qual-

ity in terms of its oxidants and reductants in relation to the receiving stream. In a large measure, it is the oxidation of ammonium bicarbonate to nitrite and nitrate that is responsible for the high positive O-R potential values in plants which are capable of complete treatment. Rudolfs (7) has shown that rate of application to filters and degree of treatment are intimately related. It remains to establish the maximum volumetric capabilities of the respective systems and yet retain the desired standard of effluent quality.

Sawyer's work (8) on the Big Sioux River, S. D., during two winter seasons, discloses that zero D.O. was established in a 35-c.f.s. river at winter temperatures by the deposition of several million gallons of effluent containing no oxidized nitrogen. Rohlich (9) has shown that in activated sludge-sewage mixtures, zero D.O. results in the depression of the O-R potential from aerobic to anaerobic conditions. Rohlich has also shown that, upon aeration, zero to negative O-R potential values were replaced by high positive potentials, inimical to anaerobic systems. Carothers (10) in Florida also demonstrated the fundamental importance of oxidation of nitrogen, although he made no O-R potential determinations.

Sampling Technic

Sampling technic is all-important in O-R potential determination, and the actual measurement should be made as soon as possible after the sample is taken. One-liter beakers are preferable to smaller vessels. This in turn involves the use of long-pattern (15 to 18 cm.) electrodes. Samples are obtained wherever possible by inverting the beaker, cutting the liquid surface with the top edge, then gradually righting it in the liquid. Agitation of the samples may disqualify them from having any representative significance, especially in the case of poorly poised systems, such as raw sewages. To avoid misleading values, the sample should be taken directly from the contents of a tank or clarifier, and not from the effluent launder or flume. Where little or no displacement is occurring it may be necessary to sample at various levels due to stratification, as in the case of ponds or lakes.

Procedure for Determining O-R Potential

The author has used exclusively throughout this work a Hellige potentiometer, equipped with a Hellige platinum electrode and calomel cell.

With platinum electrode clean, liquid junction of reference electrode renewed, zero e.m.f. of dial fixed opposite the index line, temperature compensator adjusted, selected switch on "A" or positive circuit if sample is from an oxidation process or on "B" or negative circuit if sample is from a reduction (digester) process, the electrodes are immersed in the liter beaker of sample and a time reading taken. Readings should be taken every minute on samples with which the operator has had no previous experience, and continued until equilibrium or a reverse trend is noted.

In practice, the time element is found to vary considerably at different plants, and to range from 10 to 30 minutes. Assuming that 10 min. is required to reach equilibrium in the initial sample, then all subsequent samples from that process should be given the same time element. Only the final stabilized reading is taken, any and all intermediate figures serving only to show by their increments how dynamic or static the system is. For example, when a platinum electrode is placed in an acid solution of ferrous and ferric salts, glacial acetic, or concentrated sulfuric, a comparatively stable potential will almost immediately be attained.

On the other hand, in sewage treatment practice, poorly poised O-R potential systems are encountered which require an appreciable time element to reach equilibrium. Inability to balance the circuit by operation of the potentiometer rheostat and push-button switch may be an indication that the system under examination is of opposite sign to the selector switch position. This is easily remedied by switching over on the other circuit. It is a common experience to find negative values where there should be only positive values, due to conditions which will be discussed.

Control

Having detected the offending unit or units, it is a simple matter to adopt remedial measures. Frequently the clarifier sludge withdrawal schedule requires revision to bring about more frequent withdrawals to eliminate accumulation of septic sludge (Figure 1). Pumping station wet wells are also common offenders.

Loss of oxygen balance is another common reason for failure. It may be remedied by a good housecleaning, but where clarifier detentions are long and biological unit loadings heavy, it is found necessary to introduce oxygen to the system in either the molecular or combined form, i.e., as diffused air or in the form of oxidizing compounds such as nitrates and chlorine, if the aerobic system is to survive.

The following case histories will illustrate applications of control measures.

Ridgewood, N. J.

A series of related influent-effluent O-R potential readings over an 8-hour peak load-peak flow period graphically portray (Figure 2) the work done by the Ridgewood plant. Note the lowest O-R potential of the influent (+ 73 mv.) in relation to digester contents (− 132 mv.). In a large measure, it is the negative potential of the supernatant, coupled with its high carbonate equilibrium buffer value, that interferes with biological oxidation and chemical precipitation. To minimize this the supernatant is returned as uniformly as possible over the 24-hour cycle.

Bergenfield-Dumont, N. J.

The Bergenfield-Dumont O-R potential survey (Figure 3) revealed an excellently operated plant. Due to its having both stone and sand filters in parallel, it affords a striking evalua-

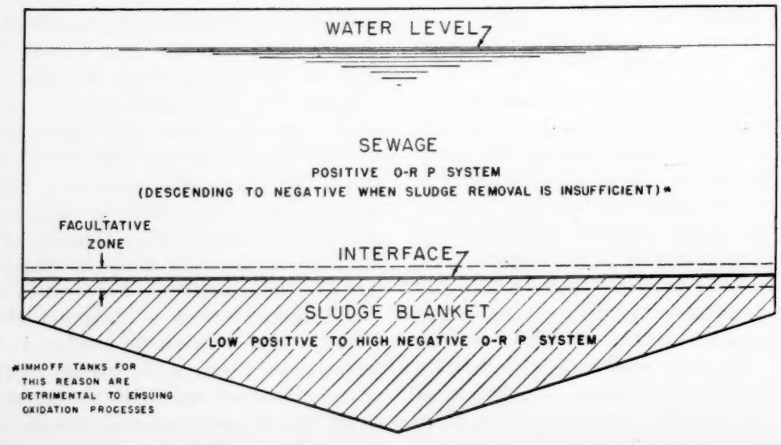
WATER LEVEL
SEWAGE
POSITIVE O-R P SYSTEM
(DESCENDING TO NEGATIVE WHEN SLUDGE REMOVAL IS INSUFFICIENT)*
FACULTATIVE ZONE
INTERFACE
SLUDGE BLANKET
LOW POSITIVE TO HIGH NEGATIVE O-R P SYSTEM
*IMHOFF TANKS FOR THIS REASON ARE DETRIMENTAL TO ENSUING OXIDATION PROCESSES

FIGURE 1.—Cross section of sedimentation tank, illustrating O-R potential conditions.

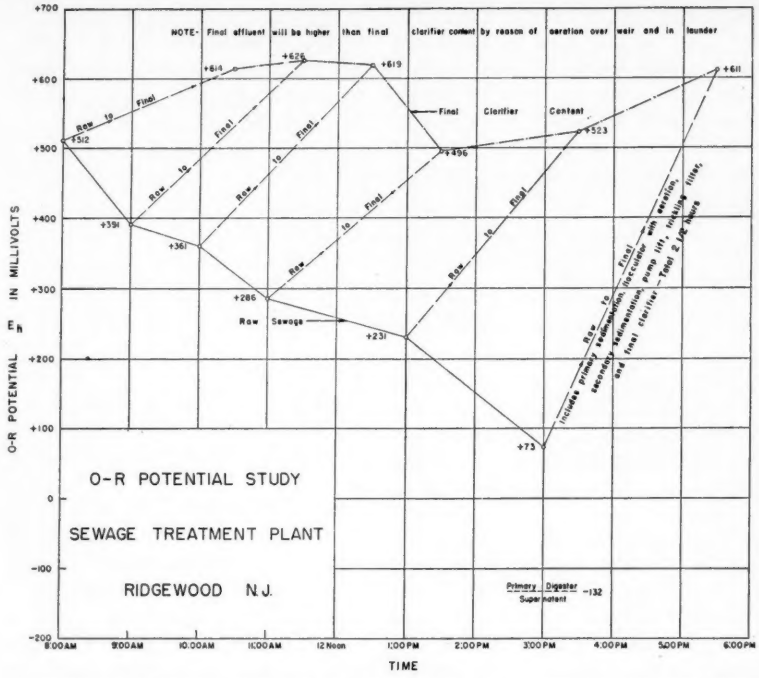

FIGURE 2.—O-R potential study in Ridgewood, N. J., sewage treatment plant.

tion of the oxidizing ability of the respective processes. Intermittent operation of the scraper mechanism was found to affect adversely the clarifier effluent by disturbing and mixing the negative O-R potential sludge layer with the positive O-R potential liquor above.

The final clarifier is not a conventional unit and lacks means of collecting and withdrawing the secondary sludge coming from the trickling filter. Emptying and cleaning operations cannot be performed frequently enough to maintain positive O-R potential values, hence anaerobic conditions result. Chlorine is used to control this condition, and the high O-R potential value of the final clarifier effluent is entirely due to its oxidizing property. When chlorine is withdrawn for any reason, negative O-R potential values replace the positive values, and septic conditions and malodors ensue.

Camp Kilmer, N. J.

Several years ago, an O-R potential survey (Figure 3) was made at this high-rate filter installation for the purpose of ascertaining the cause of its inefficiency. The raw influent was fresh, having a 283 mv. O-R potential; the primary clarifier effluent value of 311 mv. revealed no bad conditions present, but the filters depressed the O-R potential from 311 mv. to − 39 mv., indicating that reducing conditions were strongly entrenched within the filter.

Contrary to expectations, the Betz-Hellige turbidimetric determinations of SO_4 revealed no reduction of sulfate. However, the final clarifier contents were found to have a − 89 mv. O-R potential, were redolent with hy-

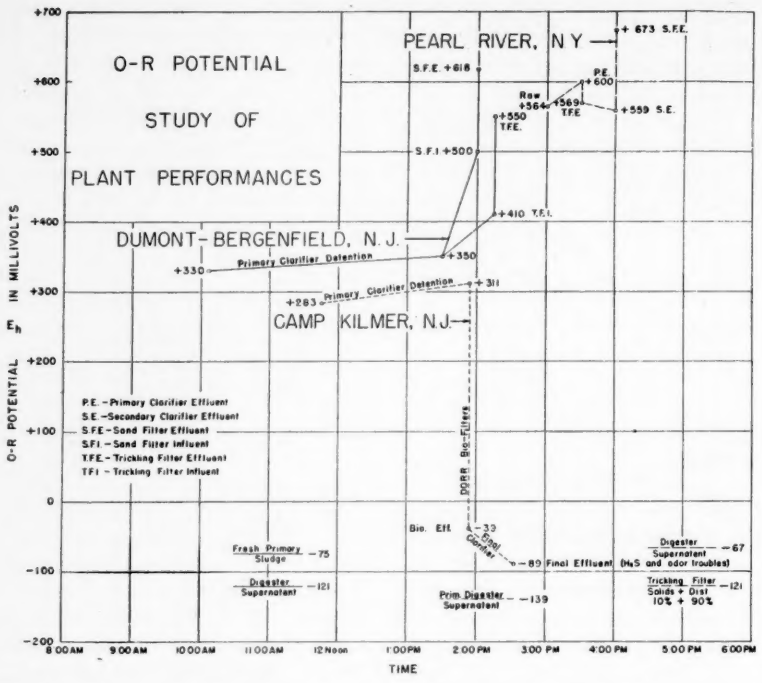

FIGURE 3.—O-R potential studies of plant performance at Bergenfield-Dumont, N. J., Camp Kilmer, N. J., and Pearl River, N. Y.

drogen sulfide, and a loss of 33 per cent SO_4 was found to occur during the detention period in these units. Here again Waksman's lag-phase phenomenon is noted, reduction of oxygen-rich compounds occurring only after the firm establishment of favorable negative potential environment. Chlorine again demonstrated its oxidizing or electron acceptor properties by transforming the O-R potential from − 89 mv. to + 99 mv. It is of interest to note, however, that no chlorine residual existed after several minutes contact. Recently the superintendent of this plant published a report describing how the thick, heavy solids had been removed from the filters, thus confirming the O-R potential diagnosis.

Pearl River, N. Y.

Serious problems have arisen at this plant due to the nature of the trade wastes included in the inflow, and the lack of a favorable volumetric ratio of domestic to trade waste.

A comparison (Figure 3) of the initial O-R potential value of the Pearl River influent with those of the predominantly domestic wastes of Bergenfield-Dumont and Camp Kilmer would seem to indicate fresher sewage. However, the high initial O-R potential is due to the penicillin and associated biologics laboratory wastes and has no virtue, since it is attended by certain anti-biotic properties peculiar to such wastes.

Even the rugged trickling filter with its inherent ability to recover from shock loads was unable to absorb this

load, and as a consequence a drop in O-R potential values occurred. This indicated that the net transaction occurring within the filter was anaerobic rather than aerobic. A test pit revealed heavy muck completely filling the voids, beginning 30 in. below the surface. By virtue of such pretreatment as was taking place, the slow sand filters were found to be performing an excellent job on the portion of the flow that they could handle.

Hackensack, N. J.

An O-R potential survey on this activated sludge plant (Figure 4) revealed that the raw sewage was quite fresh, having a 278 mv. potential as compared with a − 57 mv. potential on the Madison, Wis., raw sewage at the time Rohlich conducted his work there, and at the corresponding hour of the day. Superintendent Lehman stated that this was not representative of the Hackensack raw sewage, but was due to a heavy rainstorm of the previous day. Likewise, the secondary clarifier had a + 459 mv. potential as compared to a + 395 mv. potential at the Madison final tanks.

The return sludge O-R potential values present an interesting picture. On July 17, 1947, the Hackensack return sludge gave a reading of − 182 mv., and on the next day it gave a value of + 760 mv. An experiment was being conducted on July 17 with a deeper sludge blanket in the final clarifier. The work was terminated that evening and the normal shallow blanket was re-established during the night. Whatever virtue the deeper blanket may have, it is obvious that at summer temperature this practice cannot be adhered to, unless chlorine is applied at the aeration tank effluent to oxidize and stabilize the activated sludge.

Tapleshay (11) indicates that, under certain conditions, control of sludge index may be effected by the chlorination of both the aerator effluent and the return sludge. Re-examination of this subject, utilizing O-R potential determinations, may serve to rationalize and refine the practice.

Comparison of the return sludge

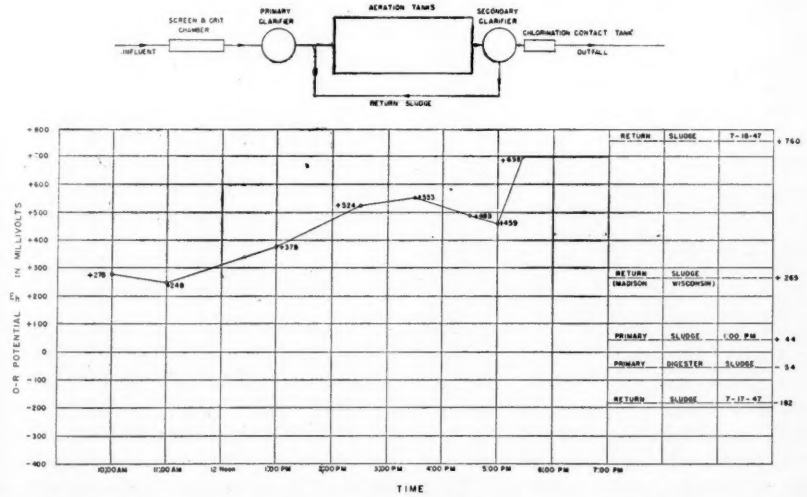

FIGURE 4.—O-R potential survey of the activated sludge plant at Hackensack, N. J., on July 17–18, 1947.

O-R potential values with the static 698-mv. reading secured at the influent to the chlorine contact basin at Hackensack reveals wherein the virtue of chlorination may reside. D.O. in the secondary clarifier doubled on July 18 as compared with July 17 as a direct result of the higher O-R potential of the return sludge, and without any increase in air delivery from the blower.

When chlorine is applied, negative (reduced) O-R potential values are changed to positive, the amount of change being related to the pounds of chlorine used. Obviously, an activated sludge in a reduced condition is detrimental to overall plant efficiency and economy.

A drop in O-R potential during primary sedimentation is typical of most plants. It should be controlled to the minimum by manipulation of detention time (wherever possible), by keeping sludge deposits at the irreducible minimum consistent with other requirements (Figure 1), and preferably reversed by preaeration.

Deposits and Growths in Sewers

Sludge deposits and resultant decomposition conditions in the sewer system, attended by negative O-R potential values, are highly detrimental to the economy and success of either chemical coagulation or biological oxidation processes. The Flora, Ill., activated sludge plant would not function until the collection system had been thoroughly flushed and divested of its accumulation of decomposing solids (12). Reducing types of biological growths should be controlled for similar reasons.

At Ridgewood, N. J. (13), the annual application of copper sulfate for sulfide control in the sewer system has been practiced for 8 years with excellent results, both aesthetic and economic. The fact that fungus creates its own optimum negative O-R potential as it becomes seeded down in the system should not be forgotten. The author feels that O-R potential studies can be applied to advantage in the control of sulfides in large installations. Objectionable conditions should not result if positive potential values are maintained throughout the trunk sewer system.

Force Mains

In Hamilton Township, N. J., there was experienced a rapid drop in pump efficiencies, which developed to the point where a comparatively new pump installation was unable to handle the incoming flow. It was ascertained that the long force main was literally filled with sulfide-producing growths. This undesirable, anaerobic, negative-potential condition was corrected by the application of copper sulfate to the pump well.

Odor Control

Fuller (14) stresses the desirability of preventive measures to eliminate the reduction of sulfates and the attendant malodorous conditions. Palliative measures in the form of chemical oxidizing agents, which effect a transient increase in potential inimical to the reducing bacteria responsible for the odor production, afford only temporary relief. Permanent relief from this problem is achieved by establishing and maintaining positive O-R potential values throughout the oxidation system, from the influent to the effluent.

Interpretation of Results

As has already been shown, oxidizing conditions are revealed by positive potential values. The role of aeration in this connection is convincingly shown by Rohlich's work on sewage at Madison, Wis. Consequently, all units of a biological oxidation system can be expected to show not only positive, but also ascending O-R potential

values, as hydraulic descent is made through the plant. It obviously becomes a simple matter to detect an offending unit or units by their failure to contribute positive values, or as is so often the case, by their reducing effect on the waste under treatment.

One important fact should be made clear at this juncture. A high positive O-R potential from a biological oxidation system, operating without internal application of oxidizing agents, may be interpreted as indicating successful operation. Other criteria will confirm this. However, concentrated sulfuric, glacial acetic, chlorine solutions, etc., all are systems in which no biological process could function, but they yield high positive O-R potential values. Positive potentials, therefore, fall in two categories: namely, those derived from dynamic biological systems, and those derived from comparatively static chemical systems which are biologically inhibitory because of other unfavorable environmental properties.

The author has found that reduction processes, such as separate sludge digesters, yield values between -100 and -200 mv. under optimum conditions. When the O-R potential approaches zero, or equilibrium, optimum anaerobic conditions no longer exist, and steps must be taken to depress the potential, restore the efficiency of the process and insure scum-free operation.

Levine (15) states that "the relative concentration of electrons in the medium become a measure of the reducing power of the system in a manner analogous perhaps to the concentration of hydrogen ions (pH) as a measure of the intensity of acidity."

O-R potential measurements may be used for many purposes in sewage treatment plant control. Following are some of the more obvious applications:

1. Detection of deposits, growths or other conditions in the sewer system or pumping stations leading to septicity or sulfide production; for observation of the effectiveness of sulfide control measures.
2. Detection of industrial wastes.
3. Detection of toxic substances or conditions.
4. Establishment of proper sludge pumping schedules at primary sedimentation tanks, through the detection of excessive sludge accumulations.
5. Detection of over-long detention periods at primary tanks.
6. Determination of internal conditions within trickling and sand filters.
7. Determination of conditions in activated sludge aeration tanks.
8. Detection of excessive sludge blanket in activated sludge settling tanks.
9. Determination of conditions in sludge digestion tanks.

O-R potential measurement may not be used as an exclusive means of gauging the detrimental effects of pollution on the receiving streams, because of the reaeration ability of streams and the interfering role of oxygen in connection with the evaluation of O-R potential determinations, which Chang (16) has described. Nevertheless, it is a useful adjunct to other determinations employed in the analysis of such problems, and it is an infallible indicator of the approach of anaerobic, putrefactive, and malodorous conditions in streams and ponds which may be rapidly losing oxygen balance. Negative values must obtain, even in heavily polluted streams, before offensive odors attend the unsightly conditions.

Conclusion

Oxidation-reduction potential has been demonstrated to be an important environmental factor in biological

processes. The determination shows promise as a guide in the control of such processes, both aerobic and anaerobic, as they are applied in the treatment of sewage and industrial wastes. Many sewage treatment plants that are now beset by internal problems not primarily due to lack of capacity may be surveyed readily by O-R potential measurements, to the end that difficulties may be diagnosed and remedies effected.

Acknowledgments

Grateful acknowledgment is made to Prof. G. A. Rohlich, Prof. Rolf Eliassen, and Mr. L. L. Langford for their interest and constructive criticism in these studies; to Mr. George B. Mebus for the preparation of the charts included in the paper; and to the operation personnel, consulting engineers and others whose cooperation made it possible to extend the studies to the several sewage treatment plants that were studied.

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MEASUREMENT AND CONTROL OF SEWAGE TREATMENT PROCESS EFFICIENCY BY OXIDATION-REDUCTION POTENTIAL—A DISCUSSION

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The importance of biological oxidation as forming the essential basis for complete sewage treatment was recognized and recorded by many of the early workers in the field. The complex nature of the biochemical reactions that take place, however, is not fully understood, and the mechanism

involved is still the subject of considerable research.

Of those types of biochemical reactions taking place in living cells or cell suspensions, oxidation-reduction reactions maintain a dominant place in any consideration which is given to the biological processes.

As has been pointed out by Mr. Hood, any arbitrary definitions of oxidation and reduction are not free from difficulty. Originally, oxidation processes were considered to be those in which oxygen was consumed, and reduction those processes in which oxygen was removed. This definition, however, was found to be inadequate in explaining certain reactions, and it became necessary to broaden the term "oxidation" to include chemical reactions which involved the loss of hydrogen. Thus, oxidation in this broader interpretation came to include loss of hydrogen as well as addition of oxygen. This concept, however, was still not broad enough to include such "oxidations" as the conversion of ferrous to ferric chloride, in which neither oxygen nor hydrogen is concerned. For the explanation of such oxidations it became necessary to broaden still further the concept of oxidation to include those reactions in which there was a removal of one or more electrons from the substance oxidized.

Thus, oxidation and reduction can be defined in terms of electron transfer as follows: In oxidation the substance suffers the loss of electrons, and in reduction the substance gains electrons.

Since these electron migrations are accompanied by potential changes and are by definition oxidations and reductions, by measurements of these potential differences quantitative studies of oxidation-reduction reactions may be effected.

In the fields of bacteriology and biochemistry important findings in explanation of oxidation and reduction processes have been made possible by O-R potential measurements. Practical use has been made of these measurements in the study of living tissues, milk, and in numerous bacterial cultures. As early as 1925, Clark, Cohen and Gibbs (1) made a few observations on oxidation-reduction potentials in sewage, and recently additional studies have been made by other investigators (2), (3), (4) with a view to making possible the application of O-R potential measurements to a more complete understanding of the mechanism of the biological oxidation of sewage by the activated sludge process.

Mr. Hood is to be congratulated for supplying additional information on this subject and for the interpretation he has made in the practical applications of the measurements taken.

Difficulties of O-R Potential Measurement

The determination of oxidation-reduction potentials is not without its attendant difficulties, and some of these difficulties are worthy of mention. While it is true that the measuring apparatus is relatively simple, it is often difficult to obtain reproducible results.

Platinum electrodes generally have been used in the measurement of O-R potentials. These must be carefully made and thoroughly checked before use. It was found in the work at the University of Wisconsin that while good checks on different electrodes can be obtained in a well-defined system such as a buffered quinhydrone solution, the same electrodes are not in agreement in poorly defined systems. It is necessary to have good agreement with a number of electrodes, and it is suggested that at least three electrodes be used in making a potential measurement.

Erratic results often occur due to "poisoning" of the electrodes. The

exact nature of this poisoning effect is not clearly understood, and it is recommended that such electrodes can be discarded before further use.

Care must be employed in the handling and cleaning of electrodes. In biological media it is found that a film will develop on the electrode that must be removed before it can be re-used. Polishing with clean filter paper or a mild abrasive such as Bon-Ami or levigated alumina to produce a fresh surface has been found to be effective.

Variations in the potential of the calomel half-cell which is generally used as the reference electrode have also been noted, and liquid junction potentials also introduce a source of error which will cause variations in the O-R potential. However, the greatest single factor in the author's work has been found to be in the variations in the electrodes themselves.

Pertinent Factors

A review of the thermodynamic and mathematical considerations involved in oxidation-reduction potential measurements is beyond the scope of this discussion, but may be found in the writings of Hewitt (5), Michaels (6) and Clark (7), as mentioned by Mr. Hood, and also in the work of Clark and associates (1).

A review of this work will reveal that the following factors must be considered in a determination of the oxidation-reduction potential of a system:

1. The ratio of the concentration of the oxidant to that of the reductant.
2. The temperature of the solution.
3. The tendency of the system to take up or give off electrons.
4. The hydrogen ion concentration.

The first factor is very important since it shows that the oxidation-reduction potential is an intensity factor and not a capacity factor. In this respect O-R resembles pH and temperature. It gives a measure of the intensity, but offers no information as to the capacity of a solution to oxidize or reduce. The capacity term in oxidation-reduction systems is referred to as the "poising effect," and is analogous to the term "buffer action" as used in connection with pH work.

The hydrogen-ion concentration of a solution has an important effect on the oxidation-reduction potential, and changes in pH will alter the values obtained. With this in mind it is necessary that pH values be obtained at the time the O-R potential is measured if proper interpretation of results is to be made.

Interpretation Limitations

In a complex heterogeneous mixture such as activated sludge and sewage, where undoubtedly many oxidizing and reducing systems, both reversible and irreversible, are concerned, it is unlikely that a simple, direct, theoretical explanation of the oxidation process will be forthcoming. Further, it does not seem apparent that present knowledge of the subject justifies unqualified statements regarding exact potential values for the aerobic and anaerobic portions of the treatment process. Biological processes are never in a state of true equilibrium, but if measurements are plotted as time-potential curves, this tool can be used to maintain better operational control of sewage treatment works.

From the work of the bacteriologist it is known that certain potentials favor the growth of aerobes and others favor the growth of anaerobes. It is known also that some anaerobes can grow even in the presence of free oxygen if the oxidation-reduction potential is at a satisfactorily low level.

The University of Wisconsin work has shown that reducing tendencies in activated sludge-sewage mixtures as measured by O-R potentials can occur

when the dissolved oxygen content drops to 1 p.p.m. In these studies, diffused-air activated sludge plant O-R values in the aeration mix were highly positive, generally around + 300 to + 400 mv. under good operating conditions.

Mr. Hood's survey at Camp Kilmer is particularly interesting in showing the marked drop in O-R potential from a highly oxidizing positive level to a negative value, clearly indicating that anaerobic action was occurring in the lower depths of the trickling filter. The confirmation of this analysis was revealed in the report of the removal of the thick heavy sludge from the filters.

It has been wisely said that it is dangerous to speculate too far, but that it is foolish not to speculate at all. There is much room for speculation in the application of oxidation-reduction potential measurements to biological sewage treatment processes. Whether or not we are in the dangerous zone of speculation can be determined only by further research, and by attempting the further practical application of this yardstick as a sewage treatment control in a manner similar to that in which it has been used by Mr. Hood.

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EFFECT OF SEWAGE CONCENTRATION ON THE ATTAINABLE DEGREE OF PURIFICATION BY THE ACTIVATED SLUDGE PROCESS

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Some years ago the author was associated with Mr. Percy Gaunt in China in treating sewages of widely different strength by the activated sludge process.

No amount of aeration would bring the composition of a strong latrine sewage down to the level easily attained with a weak water-carried sewage. To investigate the matter samples of the domestic sewage were diluted to varying degrees with tap water, and equal volumes of the resulting series of sewages of variable strength were aerated in the same way in similar aerating devices with equal volumes of the same activated sludge sample. The series of sewages in any test differed only in the degree of dilution with the water supply. By taking advantage of the variations in composition of the raw sewage it was possible to extend the tests over a wide variety of circumstances.

Aeration was carried out with a regulated amount of diffused air in cylindrical vessels of about 9 liters capacity. Mixed liquor samples were withdrawn, settled for an hour and siphoned off for analysis at intervals. Strength was measured by the British 4-hour absorption from permanganate test.

Examination of the data revealed that the more the suspended matter of the sewage was removed from consideration the more logical were the conclusions that could be drawn. Ultimately the analysis of the sewage after centrifuging was taken as the significant figure.

Table I summarizes a typical test. Six liters of each of the sewage dilutions were aerated with 2 liters of sludge at a temperature of 10° C. The absorption of the undiluted sewage with and without its suspended matter was 112.0 and 49.8 p.p.m., respectively. The composition of the settled product tended to a constant value, which was naturally attained sooner in the more dilute mixtures. Taking the 23-hour results of Table I, it was found that the series of effluents were related by the equation

$$\frac{S}{4.3} + 5.4 = E \qquad (1)$$

where S is the concentration of the centrifuged sewage in the mixture before aeration begins, and E is the strength of the corresponding effluent

TABLE I.—Four-Hour Oxygen Absorption (Permanganate) of Various Sewage Dilutions After Activated Sludge Treatment

Aeration Period (hr.)	4-Hr. Absorption From Permanganate (p.p.m.) for Indicated Sewage-Tap Water-Activated Sludge Mixtures[1]			
	2–4–2	3–3–2	4–2–2	6–0–2
1.5	10.8	13.9	19.4	29.2
5.25	8.6	9.7	11.9	19.8
6.5	8.2	9.5	11.1	17.8
23.0	8.5	9.8	10.9	14.3

[1] For example, 2–4–2 represents 2 liters sewage, 4 liters tap water and 2 liters of activated sludge.

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after 23 hours of aeration. The calculation of S for the test reported in the last column of Table I, for example, where 6 liters of sewage of 49.8 p.p.m. oxygen absorbed were mixed with 2 liters of sludge, would be

$$S = 49.8 \times 6/8 = 37.4 \text{ p.p.m.}$$

Table II shows that the agreement of observed and calculated values is good. The other tests, including some in which the effluents were filtered before analysis, also gave good agreement with similar equations.

TABLE II.—Analysis of Results of Aeration for 23 Hours as Reported in Table I

4-Hr. Absorption From Permanganate (p.p.m.)

Sewage Strength (S)	Effluent (E)	
	Observed	Calculated
12.5	8.5	8.3
18.7	9.8	9.8
24.9	10.9	11.2
37.4	14.3	14.1

Equation (1) is merely a case of the equation

$$\frac{S}{\beta} + \gamma = E \qquad (2)$$

where β and γ are constants in each series. The test cited includes the suspended matter which does not settle when clarification is complete, and is used as of more interest to the plant operator. In fact, this suspended matter has little effect on the 4-hour oxygen absorption.

In the test reported in Tables I and II the liquid settling from the activated sludge used had an absorption of 12.0 p.p.m., which presumably changed little during aeration. As the activated sludge occupied one quarter of the mixture, it may be assumed that 3.0 p.p.m. of the constant 5.4 p.p.m. was accounted for by the activated sludge substrate. This leaves a concentration of 5.4 minus 3.0 or 2.4 p.p.m. in each effluent to be explained.

Comparison of all the results of laboratory aeration tests points to an accession of colloidal matter to the liquid from the friction of the sludge particles with each other or the walls of the aerator.

Experimental

The exact absorption of the centrifuged portion of a sewage sample is dependent on the conditions of centrifuging, and the composition of a filtered effluent through paper depends *inter alia* on the type of filter paper used. The linear relation does not appear to be dependent on such details, but persists provided the same technique is used in each series of tests.

Ultimately a Type SB2 centrifuge was used for 6 min. at 3,000 r.p.m., and filtration was done by passing a definite volume through Postlip 633 C paper, which was the fastest available.

Nitrite was carefully estimated and the gross permanganate absorption was corrected for its presence. The figures therefore represent the organic matter only.

The results were erratic when the B.O.D. test was used on such effluents. A concurrent investigation showed that these effluents tended to nitrify freely during incubation.

Discussion

It is not absolutely necessary to use the suspended matter-free figure for the sewage to derive an equation of type (2) from any set of results. When this limitation is imposed there is a much narrower variation in the values of β in the different series of tests.

The adsorption isotherm has on occasion been used to explain activated sludge data. The author has consistently failed to express any of the facts

by such a relation. Taking the equation in the form

$$\frac{y}{m} = aC^{1/n}$$

where m is the quantity of adsorbent, y is the quantity adsorbed, C the equilibrium concentration, and a and n are constants, and transforming equation (1) to these symbols, it will be seen the $S = y + C$ and $E = C$. Substituting for S and E, $y = 3.3\ C - 23.2$, which is linear and totally different from the adsorption isotherm.

At the comparative equilibrium when no appreciable change of the composition of the liquids as expressed by the permanganate absorption is occurring, the author has found the linear relation so often and with such ease as to be convinced that any other result is fortuitous. Other series of tests in which the quantity of sludge is the only variable show that the equilibrium effluent is practically independent of the sludge quantity. This again is irreconcilable with the use of the adsorption isotherm.

A series of identical small plants treating volumes of sewage inversely proportional to strength would be required to extend this investigation to continuous operation.

Considered from any angle one would expect the constant γ to disappear. The liquid in the return sludge from the stronger sewage would be stronger, and the opportunity to deflocculate would be less in the weaker sewage owing to the shorter period of aeration. It is probable that the equation would for practical purposes simplify to

$$E = \frac{S}{\text{constant}}.$$

Conclusion

The attainable percentage purification in terms of oxygen consumed is primarily dependent on the composition of the sewage when freed from suspended matter. When variables are eliminated by using dilutions of the same sewage sample with tap water, the relation between influent and effluent is linear.

Acknowledgment

This work was carried out under the direction of Mr. Percy Gaunt, sometime Chief Sanitation Chemist, Shanghai Municipal Council, to whom thanks are due.

THE EFFECTS OF SEWAGE TREATMENT PROCESSES UPON OVA AND MIRACIDIA OF *SCHISTOSOMA JAPONICUM*. PART II

By Walter L. Newton,[1] William B. Figgat,[1] and Samuel R. Weibel [2]

In order to evaluate the possible consequences resulting from a focus of *Schistosoma japonicum* infection of sufficient magnitude to infiltrate a modern sewage works, experiments were set up in 1945 at the U. S. Public Health Service Hospital, Lexington, Ky., to observe the effects of sewage treatment processes upon ova and miracidia of this parasite. The results of these experiments have been the subject of a recent publication (1). The data described in the present paper represent a continuation of this investigation. Inasmuch as the application and effectiveness of the various treatment processes as commonly employed were discussed rather comprehensively in the previous paper, they need not be considered further.

Anaerobic Sludge Digestion

The earlier studies with this process were conducted at a moderate to warm temperature range, 75° to 85° F., and had indicated a survival period of approximately 3 weeks for schistosome ova. In order to evaluate the effects of a lowered temperature, two experiments were set up during the winter months at a temperature range of 44° to 65° F. In excess of 200,000 ova, the majority of which were viable, were used in each of the experiments. The viability of the ova was checked daily; samples of the sludge were placed in a suitable hatching medium and examined for the presence and number of miracidia. Periodic sludge-performance checks were made; determinations were made of the suspended solids, pH, and volatile content.

In both experiments the solids content was high, 35,000 to 60,000 p.p.m. The volatile matter in Test 1 averaged 72 per cent, and in Test 2, 66 per cent throughout the experiments. The pH in both instances averaged 7.8. In general, the sludge appeared to be digesting properly. There was less gas formation and less scum than is commonly found with sludge digesting at warmer temperatures.

In Test 1, samples consistently negative for miracidia were not obtained until after 9 weeks of digestion (see Table I). The reduction in the number of miracidia obtained from hatching tests was gradual, there being no marked reduction from one week to the next. In Test 2, negative samples were obtained after 6 weeks. There was a marked decrease in the number of miracidia obtained throughout the second week, but thereafter the decrease was as gradual as in Test 1.

It would be advantageous to perform additional experiments of this nature in order to evaluate more clearly the average survival period for the ova at this temperature range. However, it is probable that the variation in the individual survival of the ova becomes more pronounced at lower temperatures of the surrounding medium, with the result that an accurate, predictable survival period would seem difficult of establishment. Because the average temperatures in

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TABLE I.—Survival of *Schistosoma japonicum* Ova in Sludge Digesting at Low Temperatures, 44° to 65° F.

Test Number	Average Number of Miracidia Hatching from 100 Ml. of Infected Sludge										
	On Day of Inoculation	Week of Digestion									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1	175	120	114	96	45	26	8	8	6	5	0
2	155	121	56	51	26	10	12	0	—	—	—

both experiments were almost identical, and the sludge performance tests did not indicate any significant differences, it would appear that the 3-week difference in ova survival in the two tests must be explained on the basis of a difference in the lots of ova applied to the sludge. Such differences in the ova were in effect in tests conducted at warmer temperatures (1). However, at the higher temperatures these differences apparently did not result in as marked a variation in the ultimate survival periods of the ova as they did at the lower temperatures.

It seems doubtful whether the digesting sludge medium in itself had any marked effect upon the survival of the ova. Therefore, as concluded in the earlier tests with warm digesting sludge, it seems probable that the survival period of the ova was merely a reflection of the length of time the ova could survive at these temperatures in any medium which serves as nothing more than a vehicle.

From a practical point of view, it seems advisable to retain sludge infected with schistosome ova at least 10 weeks in either digestion tanks or digestion and storage tanks if the prevailing temperatures range from 45° to 65° F.

Sludge Drying

Previous tests (1) with this process indicated that at moderate temperatures, 65° to 75° F., 3 weeks of drying were adequate to render schistosome ova nonviable. It was also apparent that a reduced moisture content did not have a very marked effect upon the ova until this content was well below 40 per cent. Time appeared to be the more cogent factor. In the present series of experiments, an attempt was made to determine the effect of temperature in bringing about the destruction of ova in a drying sludge medium.

The type of drying bed and general procedure followed that described earlier (1). Samples of the sludge were examined periodically for hatchable ova and moisture content. Two temperature ranges were employed; room temperature, 60° to 75° F., and a warmer range obtained by heating a closed closet by means of an electric heater. The temperature maintained in the latter room varied between 85° and 90° F. Samples of a single infected sludge batch were allowed to dry simultaneously at the two temperature ranges.

With the moderate, room-temperature controls, the results obtained agreed rather well with those obtained in the earlier studies. Generally, it required about 3 weeks for the sludge to become negative for hatchable ova. The moisture content at the time the last viable ova were obtained varied in different tests, depending upon the rate of sludge drying (see Table II). In one test it was as high as 74 per cent after 20 days, and in another it was as low as 24 per cent after 15 days. In some instances, the ova were rendered nonviable at these moderate tem-

TABLE II.—Survival of *Schistosoma japonicum* Ova in Sludge Drying at Moderate and Warm Temperatures

Days of Drying	Per Cent Moisture and Calculated Number of Miracidia Hatching per Gram of Solids, Respectively															
	Test 1				Test 2				Test 3				Test 4		Test 5	
	60° to 75° F.		85° to 90° F.		60° to 75° F.		85° to 90° F.		60° to 75° F.		85° to 90° F.		60° to 75° F.		85° to 90° F.	
0	96	88	96	88	96	28	96	28	97	47	97	47	96	376	96	—[1]
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	88	63
2	73	93	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	82	21	82	7	82	7	88	47	88	44	—	—	83	44
4	71	61	76	7	83	47	86	—	—	—	—	—	—	—	—	—
5	—	—	—	—	—	—	—	—	—	—	—	—	82	225	—	—
6	—	—	—	—	83	22	84	5	85	60	84	21	—	—	—	—
7	67	43	72	1	80	94	72	1	—	—	—	—	76	168	66	9
8	60	47	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	—	—	63	0	—	—	—	—	76	49	82	0	—	—	61	0
10	9[2]	0	34	0	79	71	—	0	—	—	—	—	—	—	—	—
11	—	—	—	—	74	82	43	0	—	—	—	—	60	93	—	—
12	—	—	—	—	—	—	35	0	—	—	—	—	51	62	—	—
13	—	—	—	—	—	—	—	—	71	32	82	0	34	8	—	—
14	—	—	—	—	76	11	—	—	—	—	—	—	35	6	—	—
15	—	—	—	—	—	—	—	—	—	—	—	—	24	2	—	—
16	—	—	—	—	—	—	—	—	70	26	81	0	—	—	—	—
17	—	—	—	—	75	4	—	—	51	5	—	—	—	—	—	—
18	—	—	—	—	75	21	—	—	—	—	—	—	19	0	—	—
19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	74	26	—	—	—	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	—	48	2	—	—	—	—	—	—
22	—	—	—	—	—	—	—	—	39	0	—	—	—	—	—	—
24	—	—	—	—	73	0	—	—	—	—	—	—	—	—	—	—
27	—	—	—	—	74	0	—	—	—	—	—	—	—	—	—	—
32	—	—	—	—	72	0	—	—	—	—	—	—	—	—	—	—

[1] Control spilled; count of no value.

[2] Thin layer of sludge; dried out very quickly.

peratures in less than 3 weeks, but in no instance were miracidia recovered after 3 weeks, regardless of moisture content.

At the warmer temperature range, however, ova were apparently destroyed within 9 days, regardless of the moisture content. A deliberate attempt was made to keep the moisture content high by means of covers in order to control this factor. The decrease in miracidia yields was very rapid, and in one test the first negative examination was obtained in sludge with a moisture content as high as 82 per cent (see Test 3, Table II).

It would appear that, as with the digesting sludge experiments, time and particularly temperature play the important roles in the destruction of schistosome ova in a drying sludge medium. While moisture content in itself may have some effect, this effect is masked by the other factors until it drops to a low level. The similarity between the survival periods of the ova in digesting and drying sludge (approximately 3 weeks in each instance), and the similar effects that a raising or lowering of temperature had upon these survival periods, points again to the probability that these data are descriptive of the longevity of schistosome ova at a particular temperature range regardless of the enveloping medium.

It is apparent that the earlier recommendation of retaining drying

sludge infected with schistosome ova a minimum of 3 weeks before disposal is substantiated. This would hold true for moderate temperatures. If it were possible to maintain the sludge continuously above 85° F., this retention period could be reduced to 1 or 2 weeks. On the other hand, because sludge does not dry well under winter conditions, except when controlled in glass-enclosed beds, it is probable that retention periods of 2 to 3 months would have to be employed during the winter months, as indicated by the results obtained with sludge digesting at low temperatures.

With regard to the moisture content of the sludge as a determinant of when sludge is to be removed from the drying beds, a content of perhaps 20 per cent or less would be indicated if it becomes necessary to allow less than a 3-week drying period.

The Septic Tank

This process may be described as a combination of a sedimentation tank and a digestion tank. Consequently, the procedure followed consisted of filling a suitable container with raw sewage infected with schistosome ova, allowing the solids to settle to the bottom, and replacing the supernatant settled sewage with fresh, raw sewage every 24 hours. In this manner, the ova remained at the bottom of the container along with the digesting solids which accumulated as a result of the daily additions of raw sewage.

To determine the viability of the ova, samples of this septic process containing ova were introduced into a suitable hatching medium and the number of miracidia recorded. In addition, occasional examinations were made of the effluent to detect the presence of miracidia which might have hatched in the tank. A total of 11 experiments was performed, all at a room temperature of 60° to 75° F.

In the septic process, some gas and scum formation occurred, although it did not appear to be excessive. The strength of the sewage applied daily averaged approximately 390 p.p.m. in solids.

Several examinations were made of the effluent, but no miracidia were recovered. Although the miracidium counts obtained from the samples set up each day for hatching seemed erratic, a gradual reduction was in evidence in all tests (see Table III). The most marked variation occurred in the

TABLE III.—Survival of *Schistosoma japonicum* Ova in Septic Sewage with a 24-Hour Effluent Removal

Test Number	Average Number of Miracidia Hatching from 100 Ml. of Septic Sewage							
	0 Days	1–3 Days	4–6 Days	7–9 Days	10–12 Days	13–15 Days	16–18 Days	19–21 Days
1	1100	1360	1020	285	28	—	—	—
2	130	108	26	7	0	—	—	—
3	110	—	15	9	0	—	—	—
4	55	125	0	—	—	—	—	—
5	780	345	38	0	—	—	—	—
6	650	303	60	15	0	—	—	—
7	440	413	45	32	8	8	3	0
8	375	320	50	22	13	3	0	—
9	945	253	45	18	3	0	—	—
10	158	98	5	3	0	—	—	—
11	733	479	94	50	9	1	0	—
Average number miracidia	498	380	127	44	7	3	1	0

ultimate survival periods of the ova in the different tests. In two tests there were hatchings during 2 weeks of the septic process, whereas no miracidia were produced in two other tests after 1 week.

By averaging the miracidia yields for 3-day periods, rather marked reductions are obtained for each period. Assuming that these reductions indicate loss of viability in the ova, results indicate a 24 per cent loss in viability during the first 3 days, a 74 per cent loss in 4 to 6 days, a 91 per cent loss in 7 to 9 days, and a 99 per cent loss after 10 to 12 days of the septic process. In some tests, a few miracidia were recovered after 12 days.

The negative results obtained after examination of the effluent for miracidia indicate that the gradual decrease in the number of miracidium-producing ova was due not to hatching within the septic tank but rather to a loss of viability in the ova. Destruction of the ova occurred a little more rapidly with this process than with the sludge digestion process. However, survival did not exceed 3 weeks at moderate temperatures, as was the case with the other processes.

In general, it would appear that 3 weeks are adequate for killing ova in the sludge of a septic tank. In view of the practice of removing the sludge and scum from a tank only after periods of months or years, schistosome ova, with the exception of those entering 3 weeks previously, would be destroyed by the time a tank needs cleaning. In order to remove the possible hazard occasioned by the recent influent, recourse should be had to the use of temporary tank facilities allowing a 3-week storage period in the main tank prior to removal of the sludge, or to another method of storing the sludge for a 3-week period prior to its disposal.

Because of the tendency for gases to carry ova-contaminated particles of the sludge up to the surface of the tank, care must be exercised in preventing the scum thus formed from accumulating to a thickness where it will be washed out with the effluent. In addition, the sludge should not be allowed to accumulate too thickly on the bottom of the tank. Such accumulation could result in a flushing out of contaminated sludge from the bottom and also in a lowered detention period for incoming sewage. Finally, with the normal rise and fall of digesting solids and the possible intermittent turnover and mixing of tank contents, the escape of some ova-contaminated particles in the effluent is very likely.

Intermittent Sand Filtration

Previous studies (1) with filtration, using a 4-ft. depth of sand with an effective size of 0.3 mm., had indicated that schistosome ova did not penetrate beyond 3 in. when the filter was operated at the rate of 100,000 gal. per acre per day. In the studies herein reported, a smaller filter was used in order to expedite tests with various sand sizes and with various flow rates. The filter consisted of a glass cylinder, 2.4 in. in diameter and 15.7 in. in length, and containing a depth of about 12 in. of sand.

In order to evaluate the possible combinations that might be expected to occur in common practice, a total of 31 filtrations was performed with different combinations of sand and flow rates. Influent material containing thousands of ova or miracidia, depending upon the objective of the particular test, was added at a single application to the filter. For the recovery of ova, large aliquots of the effluent were centrifuged and the resulting sediment examined. For the recovery of miracidia, the effluent was allowed to stand in flasks for a period of time sufficient to enable any miracidia present to swim to the surface and be collected.

In tests with miracidia alone, both

TABLE IV.—The Efficiency of a 12-Inch Sand Filter in Removing Ova of *Schistosoma japonicum*

Test Number	Rate (gal./acre/day)	Milliliters Influent	Number of Ova in Influent	Number of Ova Recovered from Effluent
1	500,000	1370	37,000	0
2	500,000	1370	23,000	0
3	500,000	1370	24,000	0
4	1,000,000	2740	37,000	0
5	1,000,000	2740	48,000	0
6	1,000,000	2740	87,000	0

fresh and previously used sand were employed in order to evaluate the possible increase in filtration efficiency afforded by "dirty" sand.

Although some functional analyses were made, it was not possible at the time these experiments were performed to evaluate the performance of the filter, as regards B.O.D. and solids removal, as well as might be desirable.

Six tests were performed for filtration of schistosome ova alone using sand at the upper end of the size range commonly employed—0.5 mm. effective size with a uniformity coefficient of 2.2. Three filtration experiments each at 500,000 and 1,000,000 gal. per acre per day were performed. Although thousands of ova were added with each influent, no ova were ever recovered (see Table IV). Removal of solids varied with the rate of application and strength of the inoculum; from 60 to more than 90 per cent removal was effected. The failure to recover ova in the effluents at these extremes of operation indicated that further study with a smaller sand and slower rates was unnecessary.

With less effective filtration of the miracidia in evidence, a greater variety of combinations of sand size and flow rate was employed. Filtrations at rates varying from 75,000 to 1,000,000 gal. per acre per day with sand of 0.3, 0.4, and 0.5 mm. effective sizes resulted in the passage of miracidia in almost all instances (see Table V).

It was found that the critical rate (the rate at which a very few miracidia were recovered as compared with the thousands applied) for sand of an e.s. of 0.3 mm. was 250,000 g.a.d. For sand with an e.s. of 0.4 mm., the critical rate was 75,000 g.a.d. For sand with an e.s of 0.5 mm., no critical rate could be determined because miracidia would pass the sand with just barely enough influent to moisten the sand.

A rough rate of penetration of the sand by the miracidia was established in a few experiments by taking samples of the effluent at various time intervals after application of the influent. The results indicated that a few miracidia penetrated the 12-in. column at the rate of about ½ in. per minute, but that the majority penetrated at the rate of about 1 in. per minute.

In the attempt to ascertain whether "dirty" sand was a better filtering medium than clean sand, as might be anticipated, 9 of 25 tests were performed with previously used sand which had stood sufficiently long to

TABLE V.—The Recovery of Miracidia of *Schistosoma japonicum* from Effluents after Filtration of Influents Containing Thousands of such Organisms

Effective Size of Sand	Filtration Rate (gallons/acre/day)				
	75,000	100,000	250,000	500,000	1,000,000
0.3 mm. (11 tests)	— — — —	0 0 0 —	+ 0 0 0	++ ++ +++ —	++++ — — —
0.4 mm. (9 tests)	0 + 0 0	0 + 0 +	— — — —	+++ — — —	— — — —
0.5 mm. (5 tests)	— — — —	+ +++ ++++ ++++	— — — —	— — — —	++++ — — —

Key: + less than 50 miracidia.
++ 50–100 miracidia.
+++ 100–500 miracidia.
++++ more than 500 miracidia.

allow the drying out or destruction of trapped miracidia. No significant difference was in evidence; in a given series of combinations, miracidia passed used sand as well as new sand.

The failure of schistosome ova to penetrate 12 in. of sand, even when the filter was operated under what could be considered extreme conditions, points to the value of intermittent sand filtration for the removal of the ova of this parasite. Because this process usually handles sewages which would contain the ova rather than the miracidial stage (settled sewage), its value is further enhanced.

However, this process may be used after the activated sludge and trickling filter processes. As was pointed out in the earlier paper on this subject, effluents from these latter processes would contain miracidia if their influents contained ova. With filtration of these effluents usually performed at rates varying from 200,000 to 800,000 g.a.d., it is apparent from Table V that the filtration process as generally employed with these sewages would not result in an effluent free of miracidia. Therefore, it appears that filtration of biologically treated sewage contaminated with schistosome material would be of little value.

In situations where sewage is suspected of being contaminated with the parasite, intermittent sand filtration should be limited to the type of sewage in which only the ova stage is likely to occur (settled sewage or raw sewage). If it is used after a biological treatment, filtration should be operated at rates not exceeding 200,000 g.a.d., and with sand of 0.3 mm. e.s. or less.

Despite the lack of evidence in this study, it seems reasonable to expect better removal of miracidia with a building-up of a filter film after repeated filtrations. However, the value of such a factor is quite variable, and no quantitative increase in efficiency can be established with accuracy.

Summary and Conclusions

Studies of the effects of various sewage treatment processes upon ova and miracidia of *Schistosoma japonicum* are reported. Experiments with sludge digesting at low temperatures, 44° to 65° F., indicated that digestion or digestion and storage periods of 2 to 3 months are required to render schistosome ova nonviable. In view of the 3-week period required for destruction of the ova at moderate to warm temperatures, it is apparent that survival of the ova is dependent very largely upon temperature. Digestion periods for sludge contaminated with schistosome ova should be determined only after careful evaluation of the prevailing temperatures.

Experiments with the survival of ova in drying sludge produced results which agreed with those obtained in an earlier report on this subject. A survival period of 3 weeks can be expected with ova in sludge drying at moderate temperatures, 60° to 75° F. A reduction of the moisture content of the sludge apparently has no deleterious effect upon the ova until the moisture drops well below (less than 20 per cent) the spadeability content (60 to 70 per cent) commonly used as the criterion for disposal. In sludge dried at very warm temperatures, 85° to 90° F., the ova became nonviable within 9 days. With this process, also, considerable attention must be paid to the prevailing temperatures in the determination of dentention periods for drying sludge.

Tests with the intermittent sand filter indicated that this process was very effective against schistosome ova. The latter failed to penetrate 12 in. of sand of 0.5 mm. effective size when applied at rates of 1,000,000 gal. per acre per day. Such operational conditions are considered to be at the ex-

treme of least efficiency in common practice.

The filter was not efficient in checking miracidia. The latter penetrated the 12-in. depth with almost all the sand sizes and rates employed. Protection would appear to be afforded only if a sand size of 0.3 mm. or less is used and the application rate does not exceed 200,000 g.a.d.

Experiments with the septic tank process indicated that at moderate temperatures, 60° to 75° F., this process renders schistosome ova nonviable in 2 to 3 weeks, and the majority within 10 days. Because such tanks are cleaned only after months or years, all ova remaining in the tank would be dead with the exception of those entering within 3 weeks of the time the tank is cleaned. A 3-week storage period for the sludge and scum removed from the tank prior to its disposal should obviate the hazard of the recent entries.

Care should be exercised in the maintenance of the tank to forestall over-accumulation of the sludge at the surface and at the bottom, either of which conditions would allow the escape of incoming viable ova along with the effluent. In addition, some ova-contaminated particles are likely to escape in the effluent because of the continual rise and fall of digesting solids and the possible intermittent overturning and mixing of tank contents. Because low temperatures could prolong the viability of the ova, it might be advisable to establish a practice of cleaning the tanks only during the warmer months.

Acknowledgment

The authors wish to express their sincere gratitude for the splendid cooperation and facilities provided by Dr. Victor H. Vogel, Medical Officer in Charge, and by Dr. Harris Isbell, Director of Research, at the U. S. P. H. S. Hospital, Lexington, Kentucky.

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EXPLOSION PREVENTION IN UNDERGROUND UTILITY STRUCTURES IN LOS ANGELES AND VICINITY

SPECIAL REPORT OF SUBSTRUCTURE COMMITTEE,
BUREAU OF ENGINEERING, BOARD OF PUBLIC
WORKS, LOS ANGELES, CALIF.

Subcommittee on Explosion Hazards

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There are at least twelve distinct types of utility services with structures installed below the surface of public streets and roadways. These services are:

1. Sanitary sewers.
2. Storm drains.
3. Water supply.
4. Fuel gas distribution.
5. Electric light and power service.
6. Telephone and telegraph communications.
7. Street lighting.
8. Signal systems (police and fire).
9. Traffic signals.
10. Refrigeration service.
11. Steam heat.
12. Petroleum pipelines.

The service functions of seven of the above utilities are such that the underground is the only logical place for them. Originally, this location was occupied exclusively by such structures. Now, the trend in civic planning is toward the installation of all types of utility structures below the street surface. This results in a continuous excavation and construction program, with frequent damage to existing structures, greater congestion, and interference with utility services.

Statement of Problem

The probability of an explosion within a substructure vault is dependent on the presence of but two factors: (1) a vault atmosphere containing a mixture of flammable vapor and air within the explosive range, and (2) a coincident source of ignition.

In the 9-year period of 1939–47, inclusive, a total of 28 explosions in substructure vaults were recorded in the Los Angeles metropolitan area. The causes and effects of these explosions are stated briefly in Appendix A.

The frequency and occurrence of such explosions may appear low in relation to the extent of substructure and vault occupancy of the public streets. There are approximately 140,000 manholes and vaults within Metropolitan Los Angeles, suburban municipalities, and the county area.

At present, routine gas detection surveys are made in the Los Angeles metropolitan area only by certain of the utility companies, by the city of Los Angeles, and by the county engineer in various sewer maintenance districts. Records of these surveys for the past 15 years show a total of over

9,000 vaults and manholes at which the presence of combustible vapors was detected. In this period of time approximately 1,000,000 accumulated check tests were made. Though a low percentage of the total, the 9,000 positive tests represent an exposure to potential explosions at an average rate of 600 yearly. In comparison to this total, the experience report within the area indicates an average of less than eight explosions annually.

The severity rate—loss of life, personal injury and property damage—as recorded in the Los Angeles area is not a measure of the hazards. Explosions similar in type elsewhere have resulted in far greater destruction, as in Montreal several years ago when the manholes along a twelve-block length of sewer exploded; twenty people were injured, buildings collapsed, and property damage was estimated in excess of $1,000,000. It must be recognized that the consequences of an explosion are beyond control. There is always the possibility that any one explosion may result in a major catastrophe.

Sources of Explosive Products

Combustible atmospheres may occur in underground structures from (1) fuel gas leakage; (2) escapement of natural gas from oil fields; (3) presence of "sewer gas," including flammable and explosive substances improperly discharged to sewers; (4) leakage from pipelines carrying petroleum products; (5) refrigerant escapement; and (6) gases resulting from heating of electric cable insulation. The explosive ranges and ignition temperatures of gases and vapors detected in substructure manholes are given in Table I.

TABLE I.—Explosive Ranges and Ignition Temperatures of Gases and Vapors Detected in Substructure Manholes [1]

Vapor or Gases	Explosive Range—Per Cent by Vol. in Air	Ignition Temperature[2] (deg. F.)
Gasoline vapor	1.4 to 7.5	536
Gasoline—100 Octane	1.5 to 7.5	804
Butane	1.9 to 8.4	826
Propane	2.1 to 10.1	898
Butadiene	2.0 to 11.5	804
Natural gas	4.3 to 13.5	1100
Methane	5.0 to 15.0	1170
Methyl chloride	8.2 to 18.7	1170
Ammonia	15.5 to 26.6	1204
Hydrogen sulfide	4.3 to 45.5	558
Carbon disulfide	1.2 to 50.0	246
Carbon monoxide	12.5 to 74.2	1128
Hydrogen	4.0 to 74.2	1065
Acetylene	2.5 to 80.0	580

[1] Data from U. S. Bureau of Mines.

[2] As determined by laboratory tests. Under conditions existing in vaults and manholes these temperatures would be higher.

Fuel Gas

Within Los Angeles County the gas distribution system of three operating companies as of June, 1947, consisted of 9,100 miles of mains and over 815,000 service laterals. This system of pipes is subject to damage caused by:

(a) Galvanic corrosion. This action occurs where soil resistance is low, due to concentration of organic matter and/or alkali deposits accompanied by poor soil drainage. Such solids act as an electrolyte and the pipe acts as an electrode, with the result that current discharge occurs at some point on the pipe wall. At these anodic points loss of metal by pitting develops and, depending on time and current, eventually results in penetration of the pipe wall accompanied by a gas leak. Where such soil conditions exist preventive measures are adopted by the application of a di-electric coating applied to the surface of the pipe. These protective coatings are subject to injury during subsequent excavation and exposure, and under such circumstances may lose their effectiveness.

(b) Substructure damage. Insufficient allocation of space for the instal-

lation of substructures in some situations results in the encasement of gas pipes in the walls of ducts and masonry vaults subsequently constructed. Pipes under these conditions are subjected to burdens that may ultimately lead to fracture of the pipe or joints, allowing gas to escape.

Excavations performed by others often encounter gas pipes and, even though aware of the presence of the pipe, workmen will unintentionally damage the pipe or the protective coating, causing a gas leak to occur, either immediately or ultimately. Damage is not always reported; repairs often are attempted by the party responsible for the injury. Frequently such cases are uncovered later, when searching for the source of gas present in the subsoil. The experience records for damage by such interference reported by the Southern California Gas Company exceed 300 cases annually. Over 200 permits are issued daily by municipal and county authorities for excavations, which does not include excavation permits issued to gas companies. It illustrates the exposure of gas structures to interference.

(c) Structural failures. At the time of installation gas structures are subjected to pressure tests to insure against leakage. Structural defects are not disclosed, as a test to destruction is not logical. This type of failure is rare, but has occurred in such cases as ground movement by an earthquake or by shock from mechanically operated demolition tools.

(d) Electrolysis. This is caused by "vagrant" currents originating by leakage from electric railway rails carrying return current to substations, also by the ground return of D.C. equipment in industrial plants.

Underground pipes pick up stray electric railway current in areas where potentials are favorable and soil resistance is low, or through cross connections with other structures carrying current. The current carried by the gas pipes averages in excess of 2,100 amp. over any 24-hour period, with a daily maximum of approximately 4,000 amp. during peak traffic hours. This approaches 5 per cent of the total railway current returned to substations. Drainage of these vagrant currents is controlled as effectively as possible by installation of drainage bonds and reverse-current switches, but it is subjected to interferences by changes in railway traffic, alterations in underground structures, and/or damage to rail or drainage bonds. Under such situations current may discharge from pipelines to ground, and if not detected and corrected, the pipe wall is eventually penetrated.

In industrial D.C. installations, underground structures, including gas pipes, may inadvertently become part of the circuit when potentials and soil conductance are favorable, the current going to ground with damage to the pipe. Such cases are usually discovered only after leaks develop.

Field Gas

This source of gas escapement is primarily from the old Los Angeles City and Salt Lake oil fields, an area west from Elysian Park with a north boundary the extension of Melrose Avenue west to Beverly Hills, and south to approximately Pico Street. Oil and gas seepage in this area has long existed, as is evident from reports of the U. S. Geological Survey, the California State Division of Oil and Gas, and the investigations of P. Levin.*

The record indicates the abandonment of 265 wells, by methods not now known. These, together with cracks and faults in the underlying strata,

* "Geology of the Salt Lake Oil Field and Theories of Gas Escapement and Oil Seepage," March 31, 1937.

allow oil and gas to permeate the surface soils, and the gas to enter underground conduits and vaults. The USGS reports are supported by the experience of the Los Angeles City Health Department and Fire Department investigations of field gas escapement on private premises. There are also records of field gas presence in vaults of the Department of Water and Power, and records of findings by the Southern California Gas Company from inspections in this area.

Within the bounds of southern Los Angeles County there are eighteen other oil and gas fields that have been or are now producing. Many of these underlie developed areas, residential or industrial, where substructures now exist. Gas escapement, or the presence of oil seepage on the surface, is not prevalent except in the Salt Lake field.

Gases and Vapors Present in Sewers and Drains

Sedimentation of organic solids may occur in sewer pipes, caused by flat grades, crevices, sumps or obstructions that interfere with the maintenance of scouring flows. Fermentation or decomposition of these solids results in the generation of combustible gases such as methane, hydrogen sulfide and hydrogen, although there is no evidence that such generation reaches explosive concentrations.

The discharge and spillage of flammable and explosive compounds to public sewers is a most important source of hazard at underground structures. Industrial and domestic disposal of flammable cleaning solvents and similar compounds is regrettably common.

Spillage of liquids containing hydrocarbons at industrial plants, garages and service stations results in combustible vapors in sewers and drains. Gasoline spilled in the street and hosed into drains for traffic protection may actually be a greater hazard underground.

Certain chemical industrial wastes, when discharged to the sewer, will contribute to the danger of underground explosions. Examples of such substances are: carbon disulfide, used in cleaning operations and in rubber processing; ammonia, used as a refrigerant, and often dumped to the sewer in emergencies; calcium carbide sludge, which produces acetylene gas upon contact with water; sodium or potassium chlorate or perchlorate, which will react with organic matter to liberate gases at high temperatures, accompanied by instantaneous expansion and explosive forces.

In an emergency the sewer or drain is too frequently the means of disposal of any hazardous waste product, regardless of consequences and ordinances to the contrary.

Petroleum Pipeline Products

Petroleum liquid products are conveyed by pipelines installed beneath public streets and rights-of-way. These pipelines are exposed to the same sources of damage from electrolytic action or injury by interference as have been described for gas mains. Failures in these pipelines result in escape of liquids that may penetrate the substructure walls, or rise to the street surface and be washed into drains, or enter the ventilating openings in covers of substructure manholes. These liquid petroleum products may evaporate into the surrounding atmosphere, and in confined space produce an explosive mixture.

Refrigerant Vapor

Liquid ammonia is distributed by underground street pipes for refrigeration service in the business district of the metropolitan area of Los Angeles City. The system of pipes is subject to the same exposure to damage as disclosed in the discussion of fuel gas.

Ammonia vapor, contrary to common opinion, is combustible (Table I).

Electric Cable and Other Insulating Material Gases

This source of combustible gas is practically limited to D.C. electric underground circuits. A breakdown of cable insulation will produce an electric arc, which will continue if the protective fuses do not operate promptly. The heat of the arc will, by destructive distillation of cable insulation (varnished cambric, rubber or paper), produce combustible gases containing hydrogen, carbon monoxide and hydrocarbons. The lower explosive limits of these gases are given in Table I.

Electric circuit oil switches and oil-insulated transformers installed in street vaults occasionally fail electrically and produce explosions. The action of protective devices in clearing such failures is usually very fast, being of the order of 2 seconds or less. This usually limits the explosion to the one vault in which the failure occurs.

Penetration of Structures by Combustibles

The fact that combustible gas products present in the subsoil will enter conduits, sewers or drains can be accounted for by the fact that cement, concrete, brick or vitreous substructures are not built with assurance that they will be impervious to gas. If a combustible gas or liquid is present in the soil there is great likelihood that it will penetrate an adjacent structure.

Sources of Ignition

The possibility of ignition of flammable gases which collect in substructures is limited by certain fundamental conditions, e.g.,

1. There must be fuel in vapor form.
2. The vapor-fuel must be mixed with sufficient air to make an explosive mixture, or it must be escaping into air at a point where an explosive mixture can be created.
3. Heat in some form, of sufficient intensity and temperature to ignite the particular vapor involved, must be present at the place where the explosive mixture exists. Such heat may be caused by: (a) an open flame, (b) an electric arc or spark, or (c) an incandescent particle.

The ranges of explosibility—the varying percentages by volume in air of combustible gases detected in substructures—are listed in Table I. For any mixture of these gases present in an atmosphere the range would fall between the minimum and maximum for both the lower and upper range of the components.

Ignition temperatures are not absolute properties, but depend on the condition immediately surrounding the flammable product that there be a balance between rate of heat supply and heat loss, which determines whether or not a kindling temperature is reached and maintained.

Flame

Substructure maintenance crews can and should prevent any source of flame (welding and cutting torches, smoking, etc.) in suspected surroundings until a proper test is made of the atmosphere with a combustible vapor indicator after complete ventilating of the structure. This type of ignition can be controlled by discipline and, for the most part, is so controlled.

Actually there can be no control over the casual sources of ignition of flammable vapors escaping from substructures, such as burners used in street surface maintenance, auto or motorcycle exhausts, roofers' tar-pots, pedestrian smokers, and the like. Positive prevention is possible only by the elimination of combustible vapors from the atmosphere of substructures.

Arcs

Flammable gases generated by distillation of insulation material by the heat of an electric arc may be ignited by the arc itself when the proper air-gas ratio is reached. This usually will occur when the arc reaches a manhole or vault after having started in a duct. Such arcs will also ignite other gases or fuel that may be present.

Static

Static electricity is an insidious form of ignition danger. The common source of static is friction, such as continuous motion and contact between two objects—one insulated—in an atmosphere of low humidity. The potential on the insulated object may in a brief moment rise to between 2,000 and 15,000 volts or higher.

These conditions may be reproduced when a gas escapes from a pressure pipe at high velocity into an atmosphere of low humidity. The gas particles become heavily charged with static and, if impinging on an insulated body, the body will accumulate the charge and a spark discharge may occur. A leaking gas pipe illustrates a situation where static accumulation is possible, particularly where a workman may place his body in the escaping stream of gas.

Sparks

A spark of momentary occurrence may conceivably be the source of ignition of a vapor, but the probability is remote because the heat content of a single spark is barely sufficient, though the temperature is well above the ignition point. A series of sustained sparks, such as may emanate from a "frictional" lighter, does provide the necessary heat and temperature for ignition.

Protective Measures

Explosion prevention measures that are practiced by the utilities concerned with the operation and maintenance of underground structures in the Los Angeles area are outlined herewith.

Southern California Gas Company

Inspection surveys are made of all accessible street vaults, valve casings, meter boxes, and barholes over gas pipes, and tests made of confined atmosphere for the presence of combustible gases. Detection is accomplished by means of a probe and the J-W Combustible Gas Indicator. These surveys are made continuously in the metropolitan area, at the street fronts and premises of all public buildings such as schools, churches, hospitals, theaters, hotels, libraries, etc., and in advance of all street surfacing improvements.

Periodic inspection surveys are also made in areas where there are soils of severe corrosion characteristics, in the vicinity of electric railway substations, and in the areas of the Salt Lake oil fields.

The continuous program of replacement and reconditioning of pipes in the corrosive soil areas will ultimately provide a system of pipes with a corrosion-resisting coating. Subject to the availability of pipe, this work will proceed normally at a rate of about 160 miles of main pipe and 12,000 service laterals annually.

Continuous surveys are conducted to mitigate electrolysis and to control current interchange between underground structures and the return drainage to electric railway substations. Four men, equipped with special equipment and instruments, are constantly on routine and special test work. It is the duty of this crew to detect and remedy destructive effects of stray railway currents, by check of electrolysis bonds, reverse current switches and other connections.

Special electrolysis investigation surveys are conducted by joint participation with members of the Electro-

lysis Committee of Southern California, an organization of technical representatives from all major oil companies, transit lines, railroads, telegraph, telephone, water, electric and gas companies.

Los Angeles Department of Water and Power

The power system of the Department of Water and Power maintains approximately 10,000 vaults and manholes in the underground electric system. Combustible gas indicators and miner's safety lamps are carried by every crew, and are always used before entering any manhole or vault.

Five crews are continuously engaged in inspection of manholes and vaults, including the detection of combustible gases. One crew devotes full time to checking vaults and manholes for the presence of gas. In the areas where the hazard is known to be greatest the inspection is at intervals of 4 to 6 months.

The service ducts into buildings are sealed and the survey crews are required to check duct sealing on each inspection.

One installation of forced draft ventilation of ducts and vaults has been completed, with very satisfactory results. A second major installation is now in progress and a third will follow in the near future. It is contemplated that practically all of the manholes and vaults in the downtown area will be covered by forced draft ventilating systems within a year.

A survey of the direct current underground systems in the downtown area, both 220 and 550 volt, has been completed with the rehabilitation of the fusing and protection. This refusing provides protection against sustained arcing conditions, which in the past have been both the source of combustible gas and the means of ignition.

Pacific Telephone and Telegraph Company

Routine precautionary measures include the following:

1. All sub-structures crews use the combustible gas indicator for detection of combustible gases in manholes before entering same.
2. Conduit entrances between manholes and buildings are kept tightly sealed.
3. All cables are bonded together in each manhole, which equalizes potential between cables and prevents arcing.
4. Temporary bonds are placed across splices to be opened to prevent arcing while working in manholes.
5. No smoking or other source of flame is permitted within a 10-ft. radius of a manhole while it is opened.

Los Angeles City, Sewer Maintenance Division

Protective measures taken to avoid explosions in the city sewer system include a well-planned inspection service for determining the presence of explosive vapors in sewers, a continuous cleaning program of sewers and drains, and the control of waste discharges at industrial plants.

There are approximately 80,000 manholes in the city sewer system. Two men, with a specially equipped truck carrying combustible gas indicators, heavy gas indicators, and H_2S and carbon monoxide indicators, continuously cover the system. By utilizing the vacuum from the truck manifold as an aspirator the vault atmosphere is withdrawn through the indicators for rapid reading. By this means 400 manholes may be checked daily, covering the system (including rechecks) annually. Dangerous concentrations of gas, detected in manholes and corrected, average about 130 a year.

The city system consists of over 3,000 miles of sanitary sewers and 700

miles of storm drains, to which considerable industrial waste liquids are disposed. To prevent organic matter deposits or collections on the walls, a planned yearly cleaning program is followed on both sewers and drains. This is a continuous operation, requiring about 80 men. Sewers are inspected continuously for sluggish operation, and the conditions remedied. Annually, over 100 miles of sewers are flushed by hose, over 200 miles are cleaned by hand rodding or by machine, and approximately 30,000 manholes are cleaned. Storm drains are inspected annually, or oftener when necessary. About 250 miles of storm drains are cleaned annually by flushing.

To reduce formation of H_2S gas, sewage is being subjected to experimental treatment by application of a chemical solution at the upper ends of trunk lines. Results to date indicate that the chemical acts as an inhibitor to sulfide formation.

Natural ventilation is obtained in the sewer and storm drain systems at the openings in manhole covers and at the vents on house connections. Forced draft ventilation has been provided in certain large diameter trunk outfall sewers for use if required.

A program of inspection of plants discharging industrial wastes is continuous throughout the year. An engineer and ten inspectors check the operations of approximately 30,000 industrial plants. Permits are issued for industrial waste connections. A city ordinance prohibits discharge to sewers and drains of wastes or liquid materials containing more than 600 p.p.m. of oil or grease, or more than 1,000 p.p.m. of suspended solids, or any combustible, petroleum products or other material that would contribute to explosive conditions. Deviations are permitted only by approval of the Board of Public Works.

Los Angeles County, Sanitation and Storm Drain Division

An organized procedure for the inspection, cleaning and maintenance of sanitary sewers in the unincorporated area of Los Angeles County has been in effect for 20 years. The county operates 755 miles of sanitary sewers, including approximately 13,000 manholes. Detection and elimination of combustible gas and explosive hazards in the sewer structures have recently been included in the program. Adequate legislation has been provided to regulate the discharge of sewage and industrial waste.

A crew of two men, with a special truck and necessary equipment, sample the atmosphere of all manholes in the system at regular intervals. Whenever combustible gas is detected, the origin is investigated and the gas company, petroleum company, or industry responsible is notified of the hazardous condition and requested to take corrective action. Approximately 137 hazardous cases were reported during 1947. All structures are inspected semi-annually.

Three crews with appropriate trucks and equipment inspect all sewer lines semi-annually. Stoppages, deposits, rubbish and grease are removed when encountered. Gas, foul odors, or toxic conditions are reported for further investigation by the Industrial Waste Section. In addition, two crews maintain a semi-monthly schedule of flushing terminal sewers where, because of low flow, solids may be deposited and odors produced by decomposition.

A preventive program of industrial waste control includes the investigation of building plans for all new industrial construction relative to the character, content, quantity, and disposition of all industrial wastes. Proper neutralization, chemical pretreatment or oil separation is required before sewer permits are issued. Ap-

proximately 1,500 plans are investigated annually.

A survey of 5,100 existing industrial plants has revealed many hazardous conditions. A program has been established for the correction of such conditions, commensurate with the personnel available.

Routine monthly inspection and surveillance of existing pretreatment facilities, together with a policy promoting cooperation with industry, has aided the county in maintaining reasonable control over the discharge of industrial waste.

Other Cities and Districts

Incorporated cities in the county, other than the city of Los Angeles, do not maintain a gas detection program. Although one or two of the cities has gas detection equipment, it is used only for specific instances where the presence of gas is suspected, particularly in connection with sewer cleaning or repair work.

The same situation applies to the Sanitation Districts of Los Angeles County, which maintain and operate the trunk sewers, treatment plant and outfall facilities of the county system. Since most of the smaller incorporated cities discharge their sewage through the facilities of the city of Los Angeles or of the Los Angeles County Sanitation Districts, the problem of sewer maintenance and industrial waste control is not of great importance to them. However, the city and the sanitation districts do inherit many problems from the small cities, which go uncontrolled because of lack of local policing. By the time a discharge of gasoline or oil has reached the treatment plant, the violation has ceased and cannot be readily traced to the source. Through a system of permits, the county sanitation districts endeavor to control discharge of industrial wastes from industries known to have large quantities of waste.

Summary

Sources of Explosive Products

The contributory causes responsible for the presence of combustibles in manhole and vault atmospheres are not generally appreciated. Investigation over a period of years on reported cases of combustible vapors detected in sewers, drains, telephone and electric power vaults, etc., has disclosed a diversity of products responsible for the presence of potentially explosive atmospheres within the structures.

Combustible products detected in substructures, and their sources, are found to include:

1. Fuel gas escapement from breaks and leaks in gas distribution pipelines.
2. Field gas escapement from oil and gas fields.
3. Sewer gas resulting from fermentation and decomposition of organic matter and slime growth in sewers.
4. Industrial and domestic waste products discharged into drains or street catch basins, such as solvents, gasoline and combustible chemicals.
5. Petroleum products, as leakage from storage or pipelines.
6. Ammonia vapor leakage from refrigeration systems.
7. Hydrocarbon vapors from electric cable insulation and oil-filled equipment, produced by destructive distillation of insulating material under electric arcs and "shorts" in switches and transformers.

Prevention Difficulties

Removal of the contributing cause, such as the source of the combustible present in the atmosphere of a manhole or vault, is the positive solution of the problem. This is not entirely feasible, however, as certain natural phenomena, human errors and circumstances are involved which cannot be foreseen. Illustrations of such contributing factors are:

1. Escapement of natural gas in areas overlying oil and gas fields.

2. Damage to pipe structures conveying combustible products:

(a) By galvanic action in corrosive soils and electrolysis.
(b) By tools and equipment used in excavating street openings without the prior knowledge of the presence of the pipe structures.
(c) By structural defects.
(d) By construction interferences.
(e) By soil movement or settlement.

3. The practice of flushing to the sewers and drains of gasoline, oil, etc., that may be accidentally or otherwise spilled in the streets.

4. The prevalent custom of users of combustible cleaning solvents to dispose of spent and excess quantities to the sewer system.

5. The thoughtless or deliberate discharge to public sewers of industrial waste products that may be combustible or potentially hazardous.

Preventive measures are effective when there is public understanding and cooperation. Public response, however, is unpredictable.

Preventive Measures

Explosive hazards in substructures can be controlled by the adoption of protective measures that will detect the presence of combustibles in manholes and vaults and provide the means for preventing accumulations within the explosive range. This, at best, is a defense procedure, necessary because of the difficulty of eliminating combustibles at the source.

Considering the diversity of contributory causes for the presence of combustible products in substructures, the protective measures adopted and in practice are designed to reduce to a minimum the exposure to dangerous concentrations.

The functional purpose of the structures, as well as their design, require different procedures for elimination of flammable gases, although the means of detection are similar. Where the combustibles may have originated within the structure, as in sanitary sewers or electric vaults, the elimination of the cause is a distinctly different problem.

The pipelines that transport combustible products such as fuel gas, petroleum products, refrigerants, etc., are sources of combustibles that enter substructures. These lines are exposed to damage by causes beyond the control of the pipeline operator. The danger of contributory responsibility under the circumstances can be met only by continuous and rigorous inspection.

Recognized Control Procedures

1. Periodic instrumental surveys of the atmospheres of all substructure manholes and vaults for the detection of combustible vapors. Follow up, where combustibles are present, by complete purge of the manhole or vault atmosphere and elimination of the source, when possible.

2. Ventilation of manholes and vaults by forced draft where necessary to prevent concentrations of combustible vapor within the explosive range.

3. Survey by means of probe and gas-detecting instruments for the presence of combustible gas in the subsoil paralleling pipelines conveying combustible products, particularly in the areas of known corrosive soil and in regions of exposure to vagrant electric railway return currents.

4. Periodic flushing and cleaning of sewers and drains to prevent deposits of organic material and slime growth.

5. Periodic inspection of industrial plants to prevent discharge into sewers or drains of wastes that might produce explosive gases due to physical or chemical impurities, high temperatures, alkalinity or acidity.

6. Periodic check of protective equipment and fusing in direct current underground electric systems to avoid arcing conditions that are a source of combustible gas from insulation breakdown, as well as a means of ignition.

7. Periodic inspection for efficiency of all rail bonds on tracks of electrified railway systems to maintain potential gradient of the rail system at a minimum.

8. Proper design and construction of sewer and drains to insure cleansing velocities, proper ventilation, elimination of turbulence, and prevention of infiltration, so that conditions will not be favorable to the generation or release of flammable gases.

Conclusions and Recommendations

After a review of all the factors relating to the problem of explosive hazards in substructures, together with a study of the occurrence record of explosions, it is evident that the possibility of explosions in manholes and vaults cannot be entirely circumvented under present conditions.

The objective of this investigation is to reduce to an absolute minimum the probability of substructure explosions. It is obvious that a control procedure is the proper approach to the solution. It will be impossible to maintain effective control unless there is compliance with the following recommendations by the utilities involved, the responsible government agencies, and all others contributing to the hazards:

1. There should be universal adoption of the recognized control procedure.

2. *Inspection of Vaults and Manholes.* The owners and operators of underground utility structures should maintain an adequate inspection procedure for the detection of the presence of explosive products in manholes and vaults.

3. *Pipeline Leakage Detection.* The owners and operators of underground pipelines carrying combustible products should maintain an adequate inspection procedure for the detection and prevention of escapement.

4. *Training Employees.* In-service training should be given all employees whose occupation is associated with substructures, to teach them to recognize the presence of hazardous conditions and to take proper precaution.

5. *Electrolysis.* The electrified railway systems should provide adequate negative return to lower the potential gradient on the rails, in order to reduce to a minimum any current discharge to ground.

6. *Legislative Support.* Administrative bodies of city and county governments should support a program to control or prevent the discharge into sewers and drains of products likely to produce explosive atmosphere in vaults and manholes.

7. *Excavation Permits.* Municipal and county government, through a joint committee, should standardize excavation permit procedures and adopt a standard permit form. The procedure adopted should include requirements that all excavators—government agencies, franchise utilities and private parties—secure permits, and that the committee must ascertain from franchise owners the location of pipes and structures containing combustible products.

8. *Public Works Contracts.* The municipal and county government agency responsible should adopt a uniform provision in the standard specifications for construction work in public streets, requiring contractors to ascertain from the franchise owners of record the location of pipes containing combustible products, including service laterals, before starting work covered by the specifications, and to prohibit interference therewith without notice to the owner.

9. *Construction Interference.* The

municipal and county government agency responsible, by ordinance or by other regulations, should prohibit the encasement of existing pipes containing combustible products within the constructed walls of new foreign structures.

10. *Industrial D.C. Circuits.* The municipal and county government agency responsible should investigate and establish a procedure for grounding electrical D.C. equipment on premises to prevent the inclusion, directly or indirectly in the return circuit, of underground pipes carrying combustibles.

11. *Field Gas Escapement.* The city of Los Angeles, together with the California State Division of Oil and Gas, should make an engineering survey of the Salt Lake oil field to determine the extent of gas escapement and confinement under hard surface street pavements, and should study the possible venting of streets to prevent gas accumulations that enter substructure manholes and vaults in the affected area.

12. *Ventilation of Vaults and Manholes.* Where ventilation of vaults or manholes is necessary and mechanical ventilation cannot be provided, effective natural ventilation should be afforded. Reference is made to U. S. Bureau of Mines Report R–I–3496, "Ventilation of Manholes," February, 1940.

13. *Standard Practice.* Every effort should be made to establish standard practice for the design, construction and maintenance of all substructure types with respect to the elimination of explosive hazards and the contributory causes.

Appendix A

Examples of Substructure Explosions in Los Angeles Metropolitan Area

Year 1947

March—Fowler St. at Ditman. Sewer manhole explosion damaged walls of structure. Cause: hydrocarbon liquid seepage into sewer from underground storage tank; ignition by plumbers using torch while working on lateral drain.

January—Grand Ave. at 9th St. Electric power vault explosion injured three persons and caused property damage estimated at $5,000. Cause: arc in direct current circuit generated gas from insulation breakdown and ignited same.

Year 1946

December—7th St. east of Maple. Electric power vault explosion blew off cover and caused extensive damage to windows in nearby buildings. Leakage suspected from 30-in. gas main encased in concrete wall of vault. Electric cables found burnt. Possibly mixture of fuel gas and insulation gas ignited by arc.

December—Olive St. at 9th. Electric power vault explosion blew off cover, which hit truck. Fuel gas found to be leaking into conduit structure. Ignition source undetermined.

March—Yucca St. at Vine. Electric power vault explosion damaged equipment. Cause: gas main leak.

February—Hill St. at 5th. Explosion in three telephone manholes and electric power vault in late afternoon during heavy traffic. Resulted in damage to automobiles, store fronts and to vault contents, and in some minor personal injuries. Cause: ignition of gas in structures by arc in D.C. circuit; fuel gas detected in street subsoil.

March—5th St. near Broadway. Minor explosion of ammonia from pipe leak in refrigeration system vault. No damage.

Year 1945

July—9th St. at Santee. Explosion in two electric power vaults blew off covers, injured five persons and caused some property damage.

Cause attributed to insulation gas ignited by arc.

July—Huntington Dr. and Monterey Rd., San Marino. Explosion at telephone manhole blew off cover and obstructed traffic. Cause: fuel gas leakage from gas main. Electrolytic corrosion found to have attacked main, which parallels electric railway in vicinity of substation.

February—Budlong Ave. and 101st St. Telephone manhole explosion blew off cover, which struck and overturned auto trailer. Cause: fuel gas leak in service pipe.

Year 1944

December—Highland Ave. at 2nd St. Electric power vault explosion blew off cover. Cause: fuel gas from service pipe leak some distance away; gas entered conduit structure.

May—Denker Ave. and 69th St. Telephone manhole explosion injured three children. Cause: fuel gas leak from corroded gas main, ignited by children with match at manhole cover vent.

January—Vermont Ave. and 55th St. Explosion at electric power vault. Considerable fire damage and injury to workmen by burns. Causes undetermined.

Year 1943

October—San Pedro St. near 1st. Electric power vault explosion damaged vault and equipment. Cause attributed to insulation gas ignited by arc.

September—Grand Ave. and 8th St. Explosion at electric power vault caused by fuel gas leakage.

May—9th St. near Flower. Electric power vault explosion lifted cover. Cause undetermined.

March—7th St. near Rampart Blvd. Telegraph service manhole explosion (no damage) caused by fuel gas leakage.

March—Alley near Fairfax Ave. and 1st St. Explosion in electric power vault resulted in death of workman from burns. Fuel gas from leak nine blocks away entered manhole through conduit structure. Leak caused by puncture of gas main with pick when electric conduit was installed, when hole in main was plugged with wood stick.

February—Burrows Dr. near Fairfax Ave. Sewer manhole explosion blew off cover. Cause: field gas from Salt Lake oil field ignited at vent cover by boys.

Year 1941

December—Redondo Rd. and Imperial Hwy. Telephone vault explosion blew off cover. Cause: fuel gas leakage.

Year 1940

December—Fairfax Ave. and Wilshire Blvd. Two workmen burned by explosion at electric power vault. Cause: combination of field gas escapement and fuel gas leakage.

October—Market and Locust Sts., Inglewood. Telephone manhole explosion damage walls of structure. Cause: fuel gas leakage from main damaged by railway current electrolysis.

July—Cloverdale Ave. at Wilshire Blvd. Telephone manhole explosion blew cover into traffic. Cause: field gas escapement.

Year 1939

September—Broadway at 7th St. Explosion in storm drain damaged sidewalk, store fronts and windows in vicinity. Cause: pneumatic tool operator in street punctured gas main.

September—Stanford Ave. and 8th St. Explosion in street vault and signal box control caused by fuel gas leakage from broken pipe encased in concrete wall of conduit.

April—Flower St. at 3rd. Electric power vault explosion blew off cover; auto drove into opening. Cause: fuel gas leakage.

Year 1939

February—Harlem Pl. near 6th St. Minor electric power vault explosion of undetermined cause.

February—Hope and 6th Sts. Explosion at two electric power vaults damaged store fronts and windows nearby. Cause: fuel gas leakage.

SEWAGE DISPOSAL IN ARKANSAS

Arkansas, an agricultural state, has primarily a domestic sewage disposal problem, according to Marion L. Crist, consulting engineer of Little Rock, Arkansas. In a paper presented at the 1948 Annual Meeting of Arkansas Water and Sewage Conference, Mr. Crist discussed the status of sewage treatment in Arkansas and reviewed the increased activity in this field.

Arkansas' 50-in. average annual rainfall results in many continuously flowing streams which make possible relatively inexpensive water supplies and provide dilution for sewage works effluents. These two conditions combine in reducing the degree of sewage treatment required.

Of the larger streams, the Arkansas River receives the untreated sewage from many municipalities, including the four largest cities of the state. Since this river is very turbid, highly mineralized, and is not used for recreational purposes, its condition has been reasonably satisfactory from an esthetic and public health standpoint.

The upper and lower reaches of the White and Black rivers and the lower reaches of the St. Francis and Ouachita rivers are used recreationally. The latter stream also serves as a public water supply for several communities. Generally, the degree of sewage treatment provided by towns draining to these streams is insufficient to reduce pollution materially. Many of the smaller streams receive sewage wastes and, with few exceptions, justifiable nuisance conditions and complaints result.

Sewage treatment progress in Arkansas has lagged behind some other sections of the country because of antiquated financing laws, lack of public interest, and natural factors favorable to simplified sewage disposal.

Prior to 1942, only 13 plants provided secondary treatment. Of these 13 plants, only one consistently gave good results and only 3 were able to prevent the occurrence of serious complaints. Imhoff tanks were most widely used for primary sedimentation. Generally, sedimentation capacity was reasonably adequate, but digestion capacity was less than one-third of the amount needed.

During the war, the many military installations in the state were provided with reasonably adequate treatment facilities.

Modernization of state financing laws and an awakening of public interest in stream pollution control have resulted in more sewage treatment progress since 1944 than had occurred in all the previous years. Eight new plants providing secondary treatment have been constructed since 1944 and two others are under construction.

During 1947 alone, the State Board of Health approved plans for 18 new sewerage projects and 21 projects for additions and improvements. Many of these propose the use of high rate filters for secondary treatment.

Industrial Wastes

INDUSTRIAL STREAM POLLUTION REGULATIONS*

By Victor L. King

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It is most desirable that the relations between industry and state organizations be such as to bring about steady progress in the reduction of stream pollution. State organizations are seeking to set up requirements and regulations to this end, and industry is seeking to develop methods of waste treatment that will reduce pollution without excessive burden upon cost of operation. The closer these two efforts are brought together, the greater will be the reduction in pollution.

Assuming a conscientious recognition by industry of its obligation to do a reasonable job of waste treatment, and an equally conscientious recognition on the part of the state authorities to assist by developing reasonable regulations and requirements, much hope of steady progress in stream pollution abatement is justified.

It will have to be recognized at the outset by all concerned that perfection will not be attained and that industry will put substances into the streams that were not there when the rivers were in their virgin state.

The point of view that any discharge from industries is pollution cannot be sustained if any worthwhile progress is to be made in pollution abatement. There will, of course, be some isolated cases where all wastes may be barged out to sea or pumped into an abandoned mine and kept entirely out of any stream. For the most part, however, the stream is the natural and only available means of removal of the effluent to the sea, and must be used. The need, therefore, for reasonable and workable regulations is very important. Such regulations should protect the public by preventing objectionable conditions in the streams, and should protect industry by avoiding requirements that are unnecessary or that cause excessive cost to industry.

The state, representing all the people, including industry, has authority over the river. A particular industry produces the effluent. The state is concerned about what the effluent may do to the river, while the industry is concerned about what to do to its own wastes so that they do not harm the river. If this point of view prevails, then the state should develop regulations concerning the river, and industry would develop controls on its own waste treatment.

The thought is offered that rivers and streams are more than mere transportation systems. They are more than a body of moving water. They constitute a multiple natural resource, and industry's right to use a reasonable share of each of the river's natural resources must be recognized.

It is pertinent to examine a few possible regulations concerning the effects of industrial effluents upon rivers:

* One of a series of special contributions by members of the FSWA Committee on Industrial Wastes.

1. Effluents to be discharged should be so treated by industry that the receiving stream will not be disfigured to an objectionable degree, such as by the deposition of sludge banks by insoluble matter in the effluent. It is reasonable for industry to provide adequate settling capacity so that only clarified effluents are discharged, and so that the natural turbidity of any given stream is not increased. Also, the surface of a stream should not be discolored by oil, grease, foam, scum or sleek, materials which can be removed from effluents at reasonable expense.

2. Effluents to be discharged into a stream should not make the stream acid nor consume more than a reasonable part of the stream's acid-neutralizing power. The intent of such a regulation is to prevent a stream becoming acid or to prevent so much of its acid-neutralizing power being consumed that lower users of the stream would be denied a reasonable use of that same natural resource.

A study of the stream flow and alkalinity will disclose the extent of acid-neutralizing capacity at different places, and this capacity could be allocated to the existing and potential users of the stream. Frequently this problem is acute only in the few months of low-flow discharge.

3. The effluent to be discharged shall be so treated that not more than a fixed percentage of the dissolved oxygen content of the stream shall be immediately consumed, the percentage to be fixed according to the type and use of the stream. The dissolved oxygen content of streams before and after the receipt of an effluent may be easily, quickly and accurately determined. Reabsorption of oxygen from the air provides a recuperation, which also may be easily determined by stream study. It is reasonable to consider the dissolved oxygen in a stream as a natural resource which users have a right to use. By establishing a modest percentage that an industry may use, the state could prevent wastage of the dissolved oxygen resources and allocate a fair proportion to industry.

The percentage will vary with different rivers and at different places in the same river, depending upon the latter's recuperative power. By recognizing industry's right to use a determined amount of such dissolved oxygen, industry would be spared much expense in trying to destroy all the oxygen consuming power of its effluents.

4. The effluent to be discharged must not add pathogenic bacteria to the stream. The intent of such a regulation is obviously to prevent the spread of disease by the contamination of streams with these organisms. Usually such bacteria come from sewage rather than industrial wastes. Most chemical industries have effluents that are predominately acid, or they have waste acids at their disposal. It is possible to sterilize the human sewage completely and thoroughly in many chemical industrial wastes by contact with acid even at considerable dilution, and it is reasonable to permit the chemical industry to use such means of sterilization.

The foregoing regulations are offered as a basis for cooperation between industry and the state. If adopted and accepted all over the country by the chemical industry, much progress could be made.

The effect of effluents upon odor, taste, color and B.O.D. of the river is more difficult to cope with. Ample dilution is most effective in abating pollution, therefore the very great benefit of adequate dilution should not be wasted. In many streams, the volume of flow varies widely between the summer season and the balance of the year. Much dilution is wasted when high water flows away to the sea

and there is inadequate volume in the summer. The state's part in cooperating with industry could well be considered to assume the obligation of preserving the river's ability to provide adequate dilution, by action leading to the construction of flood control dams and impounding reservoirs. A more uniform dilution ratio could then be available throughout all the year.

We are at the beginning of a national effort to reduce stream pollution, and the foregoing ideas are offered for the purpose of focusing attention on what can be done now. Much remains to be learned about B.O.D. downstream, complicated by the receipt of other wastes and other sewage, and about the effect on odor, color and taste of the stream, but even these more stubborn matters must eventually yield to systematic and thorough cooperative effort.

The chemical industry is quite aware of the challenge of pollution abatement and has formed a very active committee to study the problem. This committee of the Manufacturing Chemists' Association of the United States has held several meetings at which the various aspects of pollution measurement, pollution abatement and standards of stream flow have been considered. The committee is under the chairmanship of Dr. R. W. Hess of the National Aniline Company and includes representatives of the larger chemical manufacturers of the country, including American Cyanamide Company, Du Pont Corporation, National Aniline, Monsanto, Dow, and Carbide and Carbon. Representatives of many other companies have attended the meetings. A manual has been prepared advising industry of procedures for orderly study and correction of wastes disposal problems, and a comprehensive bibliography has been issued.

The American Cyanamid Company's attack on the problem was started 10 years or more ago by the construction of the large blending and neutralizing basins at its Calco Chemical Division plant near Bound Brook, N. J., which have operated consistently to produce an effluent satisfactory to the State Board of Health.

Dow has built and operates the large plant at Midland for destroying the phenol and other taste-producing compounds in its wastes.

National Aniline has greatly reduced the B.O.D. of its waste waters and further reductions are in progress, to satisfy the Buffalo authorities.

Du Pont has tackled the problem of neutralization of acid effluents and salvage of inorganic salts.

Some wastes of organic nature may require biological oxidation, and in most cases studies must be made to determine whether such methods will work and what the loadings will be. The American Viscose Corporation has resorted to biological methods of handling certain of its wastes.

Although wastes from the chemical industry are a small proportion of all industrial wastes, they appear to be of a type that is most difficult to treat. Therefore, time must be allowed for proper study of these wastes, to avoid wastage of large expenditures upon impractical or inadequate processes of treatment.

SOME FUNDAMENTALS ON WATER POLLUTION FOR INDUSTRY*

By Roy F. Weston

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From the beginning of recorded time, man and his communities have been dependent on the characteristics, nature of occurrence, and availability of natural waters. He has used natural waters as sources of water supply for his personal and domestic needs, for his stock, for irrigation of his lands, for the fire protection of his communities, and for the operation of his industry. He has used them as sources of supply of food, as sources of power, as routes of commerce, as centers for recreation, as objects of beauty for commercial or domestic exploitation, and as drains for his wastes.

The abuse of the utilization of natural waters as drains for the wastes from various domestic, commercial, agricultural or industrial activities results in objectionable pollution and may seriously interfere with the usefulness of the waters for other purposes. The adverse effects of pollution may involve hygienic, economic, aesthetic, and legal considerations. In the case of industrial pollution, a fifth consideration may be added. This consideration is public relations.

Industrial establishments may be involved in all of the water pollution considerations mentioned above.

Hygienic Considerations

Hygienic considerations include the potential bacterial contamination by sanitary wastes of domestic water supplies, natural ice, shellfish and fish, waters used for recreational purposes, farm produce by flood or irrigation, or milk supplies by indirect means. Some specific industrial wastes may contain bacterial contamination that endangers farm-stock water supplies and also thereby indirectly endangers domestic milk supplies.

In addition, industrial establishments may discharge wastes that create tastes and odors in domestic water supplies, and thereby drive customers to unsafe but more palatable sources. They may also contain toxic ions or chemicals. Offensive conditions may be created which affect the public comfort or health, and which impair the use of the natural waters for recreational purposes.

The hygienic considerations are the most important of all, and must be given serious thought in solving pollution problems. Despite the humanitarian and possibly the economic importance of the hygienic phases of water pollution, the necessity of meeting certain standards of waste water quality or certain standards of stream quality have not been well demonstrated.

Public policy generally has been to close bathing beaches rather than to require sewage treatment, because public officials did not know how to evaluate pertinent economic and sociological factors. It has been possible to get by with gross contamination in numerous cases without knowingly causing loss of life or directly accountable economic loss.

Thus it has been difficult to define minimum standards of cleanliness.

* Presented at the Twenty-first Annual Meeting, Pennsylvania Sewage and Industrial Wastes Association, State College, Pa., August 26, 1947.

Although public health engineers established maximum limits of the bacterial contamination of waters to be used for public water supply, they set the stage for a questionable precedent when they concluded that complex and costly water purification plants were a more effective and more economical safeguard to public health than sewage treatment. Consequently, deplorable conditions have been permitted to exist.

Economic Factors

Industrial pollution may create conditions that will cause economic loss. Deterioration in water quality due to pollution may necessitate capital expenditures for new supplies or treatment facilities, or increased operating costs for domestic, industrial, or agricultural water supplies; it may damage structures; it may destroy fish and other useful aquatic life; it may impair the usefulness or desirability of riparian property; and it may, due to silt and sludge settling, cause loss of pondage storage capacity and increase costs of maintaining navigation channels.

Unfortunately there is little specific information available on the overall economics of pollution and pollution abatement. Most interests are predominantly local, and most factors are evaluated on the basis of contemporary economic or financial considerations at the local level without recognition of the more complex aspects of sound, economical public policy.

Indifference to the long-term economic aspects of the conservation of natural resources has led to gross waste in numerous cases because it was cheaper to waste than to conserve. This past indifference to the broad economic aspects of water pollution now places public authorities in the unenviable position of requesting large expenditures for waste treatment facilities without a good background on this important aspect of the problem. The localized type of thinking makes it possible to establish, understand, and sympathize with financial burden at this level, but makes it difficult to appreciate community problems and welfare.

Although there is willingness to acknowledge that it is not equitable to discharge wastes that will cause economic loss to a downstream neighbor, there has been inclination to salve the conscience with the thought that the pollution has existed for years without complaint, that an upstream neighbor is also causing pollution, that competitors and associates are doing the same elsewhere, and anyway, it is cheaper to treat polluted waters than industrial wastes. It has been felt that industries, which possibly would have to shut down if burdened with the costs of waste treatment, were more important than a "few" fish, and should not be endangered by insistence on pollution abatement. This last item is one phase of the pollution abatement problem concerning which there appears to be a change in thinking.

Wildlife enthusiasts are trying to place a dollar value on hunting, fishing and related recreational activities. Frank DuFrense of the U. S. Fish and Wildlife Service has estimated that the capitalized value of the nation's wildlife resources is about $14,000,000,000. That, is big business. The important petroleum industry is capitalized at only $18,000,000,000.

It is also estimated that the 1947 expenditures for hunting and fishing equipment, travel, etc., in the United States will equal or exceed $3,000,000,000. That also is big business. In 1946 in Pennsylvania alone about $920,000 was paid by 567,000 persons for the privilege to fish. The Board of Fish Commissioners had an income of more than $1,600,000. Statistics demonstrate that the numbers of fishermen and the amounts of money they

are willing to spend in pursuit of their sport are increasing continuously.

Thus, on the basis of economics, it may be necessary to alter some basic notions. The potential economic importance of clean streams is further illustrated by the fact that considerable sums are also spent in boating and bathing activities, and on vacation excursions to resorts on lakes and streams.

Property Depreciation

The most comprehensive study of the influence of pollution on land use, value, and earnable income was made by the Interstate Sanitation Commission on New York Harbor. Although most waterfront properties increased in assessed valuation over a period of years, changes in use could be correlated with pollution conditions.

In general, unpolluted waters were conducive to residential and recreational uses of waterfront properties. As pollution increased there was a tendency to substitute industrial and commercial establishments for the residences and, as the pollution became worse, finally to use the property for lower grade establishments such as storage yards, coal yards and building material yards which employed relatively small numbers of people.

The influence of pollution resulted in closing some of New York's shore amusement park and bathing areas. This resulted in considerable loss in transportation fares, amusement income, etc. In one case trolley fares to an amusement area dropped from a favorable summer to winter fare ratio of 18.3 in 1911 to a ratio of 1.07 in 1928. In another area, amusement licenses dropped from a peak of 21 in 1930 to none in 1936. In still another case the weekly payroll of one property dropped from a peak of $5,200 in 1925–26 to $65 in 1932–37.

In one area land values in nearby blocks increased 87.7 per cent from 1913 to 1937, while the amusement area increased only 7 per cent. During the same period land improvements in nearby blocks increased in value by about twelve times, while improvements in the amusement area fell 40 per cent. The results of this study demonstrate the adverse effects of pollution on land values.

Effects on Navigation

The economic losses due to silting is well reflected in experience with the Schuylkill River. The U. S. Army Engineers estimate that potential savings in dredging costs can justify a federal investment of about $12,500,000 to prevent further silting of the lower Schuylkill River with culm.

It is unfortunate that more information on the economic aspects of pollution are not available. If more information were at hand the need for pollution abatement might have been more convincing to hard-headed businessmen long ago.

Aesthetic Values

Industrial pollution may create conditions offensive to the eye and the sense of smell. It is impossible to evaluate such conditions economically. However, a reasonable sense of values relative to good housekeeping and legitimate civic pride should certainly motivate the establishment and maintenance of minimum standards of cleanliness. Unfortunately, this has not been the case.

Losses Through Litigation

Gross pollution may interfere with the rights of other riparian owners. If losses result from such gross pollution the pollutor may be sued for damages. One suit against a single industrial establishment claimed damages of $1,000,000, and instituted injunction proceedings to close permanently a $32,000,000 plant.

There have been relatively few large civil suits so that fear of having to pay

high damages has not provided general incentive to abate pollution. In addition to civil suit for damages, industrial establishments are subject to fines, imprisonment of their officers, and injunction, for violation of the law. In this regard, experience has demonstrated that governmental agencies administering anti-pollution laws are inadequately staffed to keep up with activities in their areas, they are inherently reasonable and lenient, and their enforcement powers are no better than the will of the political administration to prosecute. Thus numerous states have excellent anti-pollution laws and gross stream pollution.

Political Aspects

This situation also is changing. It is changing because there are now enough people in the United States who want clean streams that they could, if aroused, alter political elections. In 1946, 567,000 persons bought fishing licenses in Pennsylvania and 11,068,717 bought fishing licenses in the entire United States. That same year 678,228 persons bought hunting licenses in Pennsylvania and 9,854,313 bought hunting licenses in the entire United States. There were 1,725,505 duck stamps purchased in the United States in the fiscal year 1944–45. In the state of Pennsylvania 135,000 persons are affiliated with the Pennsylvania Federation of Sportsmen's Clubs.

There is more evidence of the trends of the times than the numbers of those interested in recreation involving wildlife. There are at least two states in which conservation and stream pollution were important issues in gubernatorial campaigns, and one in which they were issues in an attorney general campaign. In one state conservation and stream pollution abatement was agressively advocated by one gubernatorial candidate. He won the election by a majority of over 500,000 votes. It is foolish to infer that the more than 550,000 fishermen in that state were responsible for the election of that governor, but it is questionable if future gubernatorial candidates in that state will overlook their potential vote.

In the other state a man twice elected to the governor's house aroused the ire of sportsmen. An organized campaign by sportsmen's clubs contributed to his defeat at the polls. In the third state an attorney general candidate promised the prosecution of an aggressive pollution abatement program. This candidate is now the attorney general and is keeping his campaign promise.

Conservation could become a factor in national elections. The last two presidential elections were won by less than 5,000,000 popular votes. There are more than twice this number of fishermen in the U. S.

Statistically, wildlife enthusiasts could control the balance of political power. The strength of such groups is in evidence by the fact that nine different states either passed new anti-pollution laws or strengthened old laws in the year 1945, and that thirteen additional states have acted similarly since that date. In addition, federal legislation is being sponsored.

Industrial Public Relations

The industrialist should take his cue from hard facts and the trends of the times. At this time, practically every major industry needs the good will of the public and is expending considerable effort and money on public relations. Here is a golden opportunity. The industrialist can perform a public service and at the same time help himself by actively and seriously working toward stream pollution abatement. It is not enough that he comply with the minimum requirements of the Sanitary Water Board, and then wait for them to arrive at a new set of specifications. There is much to be learned, much to be standardized, millions of

dollars to be saved through research and exchange of know-how, and considerable public good will to be gained by an honest, intelligent and aggressive attitude on the part of industry to abate stream pollution.

Today industry in Pennsylvania is engaged in pollution abatement activities by governmental order. This is poor public relations. Pollution abatement is inevitable. Therefore such activities should be converted into an asset by intelligent, aggressive and prompt action. Pollution abatement activities are for the common good and are non-competitive. Thus there is good cause for industrial cooperation and little excuse for opposition to mutual assistance.

The various trade associations are doing a reasonably good job, but the most aggressive of them are but scratching the surface. They can be of considerable assistance in solving typical problems specific to their industry, but it is questionable if they can afford to involve themselves in the solution of local problems.

What is really needed is organization at a local level composed of technical representatives of the various industries. Such an organization could disseminate and encourage the exchange of knowledge of mutual interest to all industry in the area, could collect basic data, could assist governmental agencies in establishing and evaluating treatment standards and standards of water quality, and could subsidize basic research.

By virtue of their objectives, diversified membership, and national affiliations, the local and regional units comprising the Federation of Sewage Works Associations are desirable organizations for industrial support. However, time is short, aggressive action is needed, and credit for accomplishments, if credit is due, must go to the industrialists. Only industrial wastes sections or committees of these associations can meet these requirements.

Industrialists, as a group, are moving toward the objectives here suggested. Whether such a movement will be independent or affiliated with some existing organization is up to industrial leaders and interested organizations.

METHANE FERMENTATION OF A FIBERBOARD WASTE

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Recently the writers were asked to investigate methods for handling the waste liquor from a proposed fiberboard plant so as to permit its discharge without nuisance. The proposed plant will utilize about 425 cords per day of hardwoods and pine. About 390 tons of wood pulp per day will be processed from the wood used.

No chemicals are to be used in pulp preparation, but a steaming operation will liberate soluble wood sugars. These sugars must be washed from the pulp, and the resulting wash water constitutes a serious disposal problem.

The first recommendation was to plan to utilize the wood sugars in by-products, for example, the production of yeast or alcohol. Since this is not possible at present, some type of treatment will be necessary to reduce the oxygen requirements of this waste.

Outline of Problem

It is estimated that the soluble portion removed from the wood will amount to 10 per cent of the total wood used, or 91,600 lb. per day. Estimates indicate that fiber losses would not exceed 200 lb. per day. Sanitary sewage from washrooms for 400 people is also to be included.

Total plant waste is estimated at 92,000 lb. per day on a dry solids basis. Total mill effluent is estimated at 864,000 gal. per day, and the solids concentration would be about 1.28 per cent.

From B.O.D. determinations made on samples prepared in a manner simulating the proposed plant operations, the waste is expected to have a 5-day B.O.D. of about 9000 p.p.m. The 2-day B.O.D. of 4860 p.p.m.—54 per cent of the 5-day value—was taken as a safe basis of design. The latter figure includes a safety factor of approximately 15 per cent.

From the estimated B.O.D. of 9000 p.p.m. and the estimated daily flow of 864,000 gal., the total B.O.D. is assumed as 64,700 lb. per day, and is equivalent to the waste from a city of 380,000 population.

The flow of the river into which the plant waste is to be discharged is very flashy, with a peak flow of 270,000 c.f.s. and a flow of 2500 c.f.s. or more obtaining 5 to 8 months per year. Records from 1927 to 1942 indicate that the flow is rarely below 1100 c.f.s., although it has been as low as 350 c.f.s. for several months at a time. Assuming that special treatment would be possible in the periods of low flow, at least 1100 c.f.s. would be available most of the time to satisfy the oxygen requirements of this and other wastes to be discharged. Of the 1100 c.f.s., about 140 c.f.s. is reserved for the use of others, so that only 960 c.f.s. would be available for dilution of the waste from the proposed mill.

If the normal concentration of dissolved oxygen is 7 to 8 p.p.m., and if 4 to 5 are assumed to constitute a satisfactory stream condition, 3 p.p.m. of oxygen are available to satisfy a pollution load. This corresponds to 16.2 lb. of oxygen per day per c.f.s. of stream flow, or 15,552 lb. per day in this case.

At the suggestion of the local sani-

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tary authorities it was assumed that the 2-day B.O.D. could be of a quantity equal to the proposed 3 p.p.m. of dissolved oxygen available, due to stream characteristics below the proposed plant site. The estimated 2-day B.O.D. was 4860 p.p.m. With 864,000 g.p.d. of wastes, this corresponds to 34,943 lb. daily B.O.D. load. On this basis, 15,552/34,943 or 44.5 per cent of the 2-day B.O.D. will be met by the dissolved oxygen of the stream, and 55.5 per cent must be removed or satisfied by other means.

Since even the 55.5 per cent load would have a population equivalent of over 200,000, it was apparent that the cost of a treatment plant would be an appreciable item. A study of cost and applicability of various treatment methods was therefore made.

Cost Comparison of Various Processes

The waste carried practically no suspended solids and no organic matter which could be thrown down by coagulants. The available methods were therefore (1) biological filtration (trickling or sand), (2) activated sludge, (3) anaerobic fermentation, and (4) lagoons.

Activated sludge did not appear feasible because of capital and power costs, and lagoons alone were found by experiment (cited below) to be inadequate. Buswell, Boruff, and Wiesman (1) calculated the cost of installations for the treatment of milk wastes by three methods. Their actual figures are no longer applicable, but the ratios of costs should still be very nearly correct. The anaerobic methane digesters were found to cost only 7.45 per cent of the cost of trickling filters, or 2.98 per cent of that of sand filters, all on the basis of equivalent loadings of total solids. From these figures it was apparent that if the methane fermentation could be applied with a sufficiently high loading, and if its efficiency were satisfactory, this would be the least expensive method of treatment. Accordingly, laboratory experiments were undertaken to determine whether this type of waste could be treated by anaerobic fermentation, and if so, what loading could be used.

Laboratory Fermentation Experiments

At regular intervals, batches of a wood extract were prepared by a process and from materials similar to those to be used in the final plant, and were kept under refrigeration to prevent preliminary attack by bacteria or mold.

The first waste prepared contained only 0.6 per cent total solids. Later samples were generally more concentrated, and were diluted with distilled water to a concentration of 1.10 per cent total solids.

The fermentation of this liquor was first attempted in a single-stage digester of 1.5-liter capacity (2). Salts considered essential to the organisms active in the methane fermentation were added to the liquor and to the water used to dilute the waste at the beginning of the fermentation. The amounts added were as follows: 100 mg. of $MgHPO_4$ per liter, 100 mg. of K_2HPO_4 per liter and 343 mg. of $(NH_4)_2CO_3$ per liter, equivalent to 100 mg. of nitrogen. This was thought necessary in the preliminary work since the samples were made up with Lake Michigan water, which has a low total solids concentration composed almost entirely of $CaCO_3$.

A 100-ml. portion of the 0.6 per cent waste was inoculated with 250 ml. of actively digesting sludge from the Urbana and Champaign Sanitary District sludge digester. This was then diluted to a total volume of 1500 ml. Within 24 hours, gas production started. The volatile acid concentration (3) was found to be very low (200 p.p.m.), and the daily feeding was gradually increased until, after

8 days, it reached 250 ml. per day (1.0 gram dry solids per day). At this point the volatile acid concentration rose sharply. The feeding was held constant for 3 days and then discontinued, for gas production had completely stopped and the volatile acid concentration had risen to 940 p.p.m.

Two more fermentations were then set up, using as inoculum 500 ml. of sludge from the same source as before. As in the previous fermentation, gas production decreased and volatile acid concentrations increased, in this case, after 11 days. The rate of feeding was immediately lowered and the cultures survived, although their operation was poor. Volatile acid concentrations averaged 1000 p.p.m. or over, with a feeding rate of only 0.733 gram dry solids per liter per day (0.054 lb. per cu. ft.).

Two-stage digestion was initiated at this point, using the two digesters already in operation. Direct connections between the two stages were not feasible with this apparatus, so back circulation from secondary to primary, and normal flow from primary to secondary were simulated by manual transfer of the desired measured volumes. Two-stage digestion was used throughout the remainder of this work, so the total digester volume was 3.0 liters. The purpose of two-stage digestion was dual. The high volatile acid concentration indicated that the B.O.D. of the effluent would still be quite high, which could be overcome by two-stage digestion. Also, the secondary digester offers a means of dilution in case of dangerous concentrations of volatile acids in the primary. Thus chances of losing a culture through over-feeding are minimized.

With two-stage digestion it was found that a loading of only 0.59 gram dry solids per liter per day (0.04 lb. per cu. ft. per day) was possible, the volatile acid concentration averaging 1200 p.p.m. in the primary, and 300 p.p.m. in the secondary. This loading, of course, was far too low to make the process seem attractive from a financial viewpoint.

In the initial period of each of the three fermentations, excellent operation had been noted, higher feeding rates being possible than could be attained after a few weeks, or even days, of operation. It was also found that if more sludge was added to the fermentation, a similar brief period of high activity resulted. The sludge used in these inoculations contained approximately 2000 p.p.m. of nitrogen, 30 per cent of which was present as ammonia, or its salts, and 70 per cent of which was combined organically. Analysis of the digester liquor during a period of high activity showed a nitrogen content of 146 p.p.m. The nitrogen concentration in the waste was increased to 200 p.p.m., since it seemed possible that the higher concentration of nitrogen might be at least partly responsible for the periods of high activity. Some improvement was noted after this change.

Another factor considered was the acid production found to take place in the early stages of the fermentation of sugars. It has been demonstrated by Todd (4) that the first step in the fermentation was the production of acids, mainly acetic, which were then fermented to methane and carbon dioxide. This would naturally result in a rapid pH change, the amount of sugars fed and the buffer capacity of the medium controlling the magnitude of the change. In a full scale digester, this change would be minimized by continuous feeding. In a laboratory scale digester, the feeding rate would be too small to make it practical. The most obvious approach was used—feeding in three portions at 6-hour intervals during the day.

This change also helped, making a higher feeding rate possible. However, the pH was still found to vary

from 6.6 at the time of sampling in the morning to 5.0 or 5.5 after 6 hours.

The addition of lime or soda to sludge digesters and to fermentations of this type is not accepted as good practice in general. Indiscriminate addition of alkaline materials causes the production of volatile acids to increase or, more likely, it retards their decomposition to methane and carbon dioxide, thus aggravating an already unfavorable condition instead of alleviating it. In this case, however, the liquor was made up from Lake Michigan water, which has only 125 p.p.m. of alkalinity, and further diluted with distilled water. Some buffering would be expected from the phosphates and ammonium carbonate added, but this pH variation still seemed too great. An additional 200 p.p.m. of $NaHCO_3$ improved matters, and raising this to 300 p.p.m. gave results which were considered satisfactory. Feeding was increased to 2.2 grams dry solids per liter per day (0.16 lb. per cu. ft. per day), with volatile acids averaging 500 p.p.m in the primary digester.

Operating Costs (Chemicals)

The process having proved satisfactory from the standpoint of operation and possible loading rates, two considerations were yet to be examined: first, the efficiency of the process in actual B.O.D. reduction, and second, the operating cost of the process. These were actually taken up in the reverse order, for the gas yield indicated high efficiency in B.O.D. reduction, and whatever changes would be necessary for economy should be made before final assessment of the efficiency.

The costs of salts added to the waste before fermentation were calculated from prices quoted in *Chemical and Engineering News* at the time (January, 1947), and are listed in Table I. The cost of these additions, estimated at $725 per m.g. of waste to be treated, would vary with time, but this estimate at least indicated the order of magnitude of the cost and showed that some form of economy would be necessary.

TABLE I.—Cost of Salts Added to Waste

Salt	Dosage		Cost ($)	
	P.P.M.	Lb. per M.G.	Per Lb.	Per M.G.
K_2HPO_4	100	830	0.121	100.50
$MgHPO_4$	100	830	0.137	113.30
$(NH_4)_2CO_3$	646	5390	0.085	458.00
$NaHCO_3$	300	2500	0.0225	56.25
Total	—	—	—	728.05

The phosphates were eliminated first. Potassium and magnesium would be expected to be present in some small quantity in any water supply, and analysis indicated that phosphorus was present in the waste in a concentration of 15 p.p.m. After 20 days without any addition of phosphate, the concentration in the digesters approached what appeared to be a constant value of 13.5 p.p.m. as phosphorus. This was sufficient for the process, for no decrease in activity could be noted as a result of this step.

The nitrogen requirement could be supplied by either of two fairly inexpensive sources—ammonia or urea. Ammonia had been found satisfactory in past experience, but urea had never been tried, to the authors' knowledge. Substitution of urea for the ammonium carbonate gave continued good results. For further economy, the added nitrogen was reduced to 100 p.p.m. without any deleterious effect being noted. Apparently the slight increase in activity observed when the ammonium carbonate concentration was raised was due to the slight increase in buffer capacity from this source.

In connection with the nitrogen requirement, observations were made to determine the nitrogen lost as sludge. When the digesters were inoculated,

25 grams of long-fiber asbestos were added to serve as a nidus for the bacteria. In addition, the sludge added as inoculum contained 4 per cent solids. This solid material is necessary to the fermentation, and when fermentation is active it is impossible to obtain an effluent which is completely free of suspended solids. To conserve these solids, the digester effluent was added to a large beaker having a 6-day retention period, in which the solids settled satisfactorily, leaving a clear liquor. Some solids were occasionally returned to the digester to maintain the proper balance.

TABLE II.—Nitrogen Analyses

Sample	Nitrogen as NH_4 (p.p.m.)	Kjeldahl Nitrogen (p.p.m.)
Waste as fed	180	48.1
Clear effluent from secondary	35.2	59.5
Sludge from beaker	103	789

It was found that this practice also conserved nitrogen, as is shown by the analyses in Table II. These analyses were made during the period when the nitrogen source was 200 p.p.m. of nitrogen added as ammonium carbonate. The nitrogen added is apparently fixed in the cell material and thus concentrated in the sludge. Returning this material to the digesters will therefore conserve nitrogen and reduce the quantity which must be added to the waste before fermentation. No specific provision has been made for accomplishing this at present because of the difficulty in estimating the amount of sludge to be obtained.

Anhydrous ammonia was found to be the least expensive nitrogen source, being available in carload lots at $59 per ton. At this price, the addition of 100 p.p.m. of nitrogen would amount to only $29.90 per m.g. of waste.

The addition of sodium bicarbonate would be unnecessary in the final plant, and therefore this expense was disregarded. Its use in the laboratory was made necessary by the low alkalinity of the water used in preparing the samples. Both surface water and ground water are to be available in the plant, and by blending these the alkalinity can be controlled as desired. Even if more alkalinity should be necessary, it could be added inexpensively as lime.

Thus the total cost of chemicals was estimated at only $29.90 per million gallons.

Effect of Lagooning

While the fermentation experiments were in progress, samples of the waste were exposed in beakers in the laboratory to simulate lagoon conditions. Unseeded and untreated samples developed a sour odor and showed little improvement in oxygen demand. When 100 p.p.m. ammonia was added and the samples seeded with a small amount of sludge, no odor was produced and there was a 20 per cent decrease in B.O.D. in a 30-day period.

The effect of lagooning on the digester effluent was determined in a similar manner. The effluent from the second stage digester was held in the laboratory in a large open beaker for several weeks. It had a slight woody odor when drawn. This odor decreased on "lagooning"; there was a small deposit of sludge and a 2.6 per cent decrease in B.O.D. in 6 days.

Overall Efficiency

The efficiency of the process was then determined through B.O.D. determinations. Table III lists the results of these analyses on a sample which had been diluted to give a B.O.D. of 5350. The efficiency indicated by these analyses is very high —94.1 per cent for a two-stage digester with a 5-day retention period,

TABLE III.—B.O.D. of Digestion System

Sample	5-Day B.O.D. (p.p.m.)	Per Cent of Loading Removed	Per Cent of Total Removed
Waste before treatment	5350	—	—
Primary digester effluent	810	84.9	84.9
Secondary digester effluent	320	60.5	9.2
Lagoon effluent	180	43.8	2.6

or 96.7 per cent when the effect of 6 days' retention in a lagoon is included.

Suggested Solution of Problem

Assuming 80 per cent removal of B.O.D. by fermentation, which allows a large safety factor, it would be necessary to treat 70 per cent of the waste in order to reduce the B.O.D. load on the stream to 15,552 lb. per day, the permissible amount with 1100 c.f.s. of dilution. This B.O.D. load would include 4860 lb. per day for the 600,000 g.p.d. of waste given treatment, and 10,692 lb. per day for the remaining 264,000 g.p.d. of waste discharged without treatment.

To handle the problem during periods when the stream flow is less than 1100 c.f.s., it is proposed to build a holding basin, or lagoon. This would

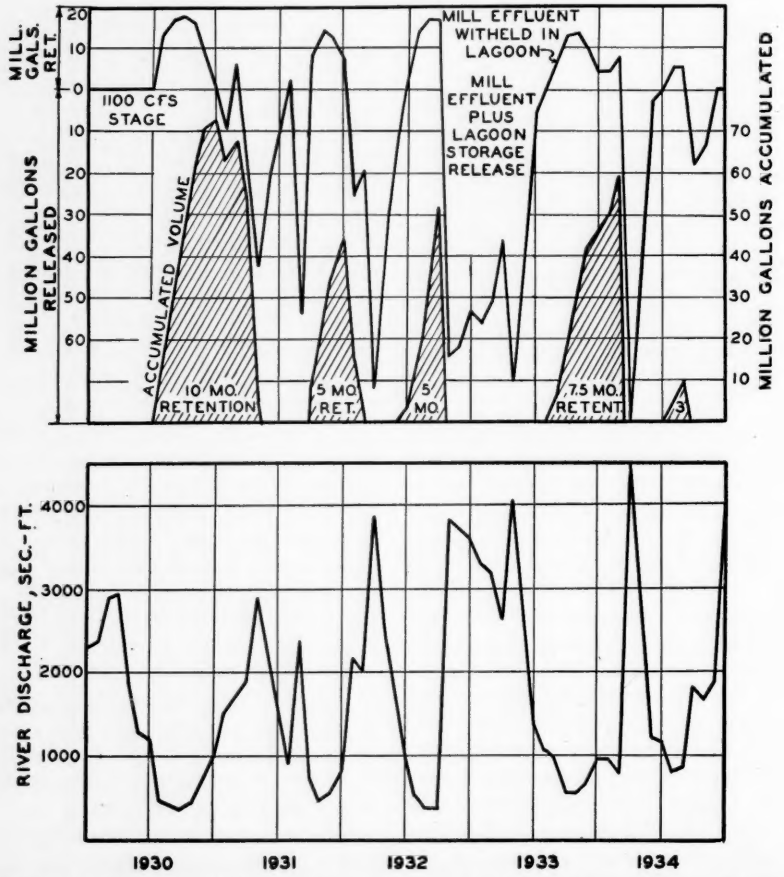

FIGURE 1.—Chart illustrating operation of lagoon system under varying conditions of river flow.

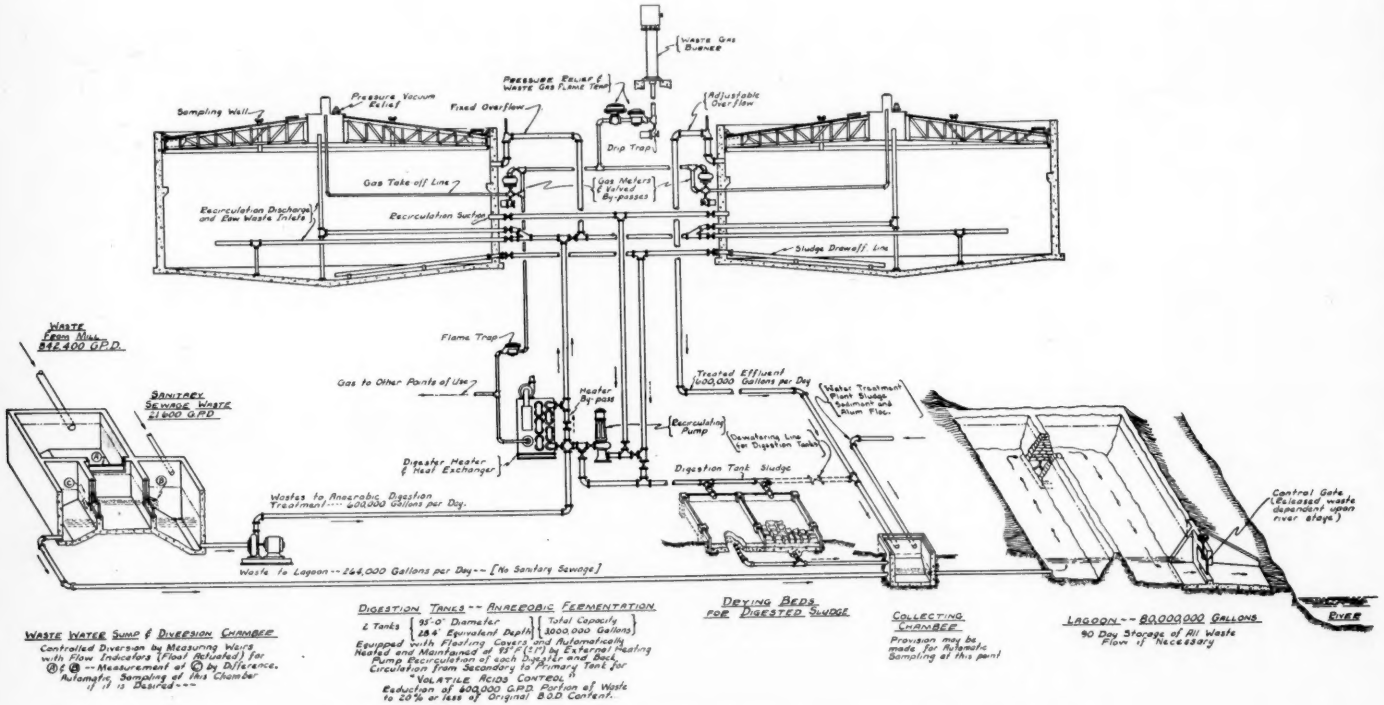
Waste Gas Burner
Pressure Relief & Waste Gas Flame Trap
Sampling Well
Pressure Vacuum Relief
Fixed Overflow
Adjustable Overflow
Drip Trap
Gas Take off Line
Gas Meters & Valved By-passes
Recirculation Discharge and Raw Waste Inlets
Recirculation Suction
Sludge Drawoff Line
Waste From Milk 842,400 G.P.D.
Sanitary Sewage Waste 21,600 G.P.D.
Flame Trap
Gas to Other Points of Use
Heater By-pass
Treated Effluent 1,000,000 Gallons per Day
Water Treatment Plant Sludge Sediment and Alum Floc.
Recirculating Pump
Dewatering Line for Digestion Tanks
Digester Heater & Heat Exchanger
Digestion Tank Sludge
Wastes to Anaerobic Digestion Treatment --- 900,000 Gallons per Day.
Waste to Lagoon -- 264,000 Gallons per Day -- [No Sanitary Sewage]
Control Gate (Released waste dependent upon river stage)
RIVER
Waste Water Sump & Diversion Chamber
Controlled Diversion by Measuring Weirs with Flow Indicators (Float Actuated) for ②, ③, ④ -- Measurement of ① by Difference. Automatic Sampling of this Chamber if it is Desired ---
Digestion Tanks -- Anaerobic Fermentation
2 Tanks { 95'-0" Diameter / 28.4' Equivalent Depth } { Total Capacity / 3,000,000 Gallons }
Equipped with Floating Covers and Automatically Heated and Maintained at 85° F (?) by External Heating Pump Recirculation of each Digester and Back Circulation from Secondary to Primary Tank for "Volatile Acids Control"
Reduction of 600,000 G.P.D. Portion of Waste to 20% or less of Original B.O.D. Content.
Drying Beds for Digested Sludge
Collecting Chamber
Provision may be made for Automatic Sampling at this point
Lagoon -- 80,000,000 Gallons
90 Day Storage of All Waste Flow if Necessary

FIGURE 2.—Layout of proposed fiberboard waste treatment and disposal works.

have to withhold the entire flow for the longest dry period.

A study of the monthly average stream flow records showed the longest and most severe dry weather conditions to have occurred in the years 1930 to 1934, inclusive. Figure 1 was drawn to show the amount of treated waste which would have had to be withheld if the system outlined above had been in operation. This chart indicates that 76,000,000 gal. of waste would have been the maximum accumulation.

Although a 20 per cent reduction in B.O.D. will occur when this waste is held for 90 days in a lagoon, as shown in laboratory studies, this factor is not considered, but left as a safety factor. It is planned to use the lagoon only at times when the river stages will not permit the total normal flow from the treatment plant and the 30 per cent of plant wastes not treated. This lagooned waste is to be discharged at a controlled rate during periods of high flow so that the lagoon discharge plus the regular discharge does not exceed the dissolved oxygen available. This operation will be carefully controlled on the basis of stream gauge reports, dissolved oxygen determinations, and B.O.D. determinations.

Final Design

The final plant layout is shown in Figure 2. The tanks are designed for a loading factor of 0.16 lb. volatiles per cu. ft., which requires 400,000 cu. ft. in two digesters. An 80,000,000-gal. lagoon is provided to retain the effluent when the flows are less than 1100 c.f.s. The cost complete is roughly estimated at half a million dollars, or about $2.50 per capita equivalent to the B.O.D. load removed.

Summary

A wood extract waste to be discharged from a proposed plant for the production of wood fiber building board products was found to require 55 per cent reduction in B.O.D. on the basis of B.O.D. determinations, estimated volumes, and stream flow records. Laboratory experiments indicated that the anaerobic methane fermentation would produce over 90 per cent reduction.

The proposed process for treatment consisted of two-stage anaerobic digestion of 70 per cent of the waste, after addition of 100 p.p.m. of nitrogen as ammonia, costing about $30 per m.g. treated.

An 80,000,000-gal. lagoon is proposed to act as a holding basin during periods of low stream flow, being emptied during periods of high flow. Studies of stream flow records indicated that the lagoon would be unnecessary at most times, and that this capacity was sufficient for the longest dry period on record.

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MILK WASTE DISPOSAL *

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Not so many years ago most dairy products were produced, processed and sold by the farmer. Any waste products in these earlier days were so small in quantity that when they were thrown away the area over which the nuisance might extend would be very small. Usually the farmer used the waste products as food for some of the farm animals.

During a somewhat later period small creameries and cheese factories were scattered across the countryside, usually located within horse hauling distance of the farms that supplied them. These small factories had appreciable amounts of waste waters that caused some minor local nuisances. With improvements in means of transportation it was possible to haul milk greater distances and thereby permit the construction of larger processing plants. Galligan and Levine (122) state that in 1932 there were 475 creameries in Iowa that produced six times the amount of butter that twice that number of creameries produced in 1894.

Early in this period it was concluded that it was necessary to develop means of disposing of milk wastes. The USPHS cooperated with the Dairy Division, Bureau of Animal Industry, U. S. Department of Agriculture, in carrying out experiments at Grove City, Pa. Phelps (153) began this research in May, 1916, and continued it until October, 1917, when the study was terminated under the the opinion that the milk waste disposal problem had been solved. Now, 30 years later, the problem of milk waste treatment and disposal still awaits practical solution.

It is certain that the increasing size of milk processing plants has contributed materially to the problem of waste disposal. Milk plants that process 500,000 lb. of milk per day are common.

Character of Milk Wastes

Milk, being a balanced food for many animals, might be considered as a material that would serve as a suitable medium for the growth of organisms. This it is, but the decomposition of milk constituents results in the production of malodorous by-products.

Much of the waste from a dairy is whole milk from drips and washings. In these times whey, buttermilk, and skim milk should not be considered as waste products, because no company can afford to treat quantities of these materials in a waste disposal plant.

Whole milk, according to Van Slyke (181), Roberts (160), Eldridge (58), and the Ohio Department of Health (87), is made up of the materials shown in Table I. Eldridge (58) gives the total solids of milk as 125,000 p.p.m.; the volatile solids at only slightly less. The Purdue Laboratory reports a finding of 131,500 p.p.m. total solids in whole milk and 240,000 p.p.m. in condensed milk. This is given to show that it takes less than 0.002 gal. (about 8 ml.) of milk to be equivalent to a gallon of domestic sewage.

* Presented at First Annual Meeting, Kentucky-Tennessee Industrial Wastes and Sewage Works Association, Louisville, Ky., September 22–24, 1947.

TABLE I.—Constituents of Whole Milk

	Water	Fat	Casein	Protein	Albumin	Lactose	Ash
Van Slyke	87.10	3.90	2.5	—	0.7	5.10	0.70
Roberts	87.25	3.80	—	3.50	—	4.80	0.65
Eldridge	87.30	3.60	—	3.80	—	4.50	0.80
Ohio Dept. Health	87.40	3.75	—	3.29	—	5.14	0.70

Even though Trebler (175) and Warrick (185) have written extensively on the necessity of saving drops of milk to reduce the expense of waste treatment facilities, many of the companies have failed to heed the information, and continue to report the 2 per cent losses in their plants. Based upon analyses of the waste, it has been impossible to find many references that substantiate the 2 per cent figure so often used. The loss of 2 per cent reported by Montagna (143), when calculated, using the milk production of 60,000 lb. per day, waste flow of 50,000 g.p.d., and total solids adjusted for soluble minerals in the water, would exceed 3 per cent. The studies by Mallory (131) on the milk wastes from the Highland Dairy Products Co. at Doe Run, Pa., show losses of 3.17, 3.85, and 9.5 per cent.

It is questionable whether it is a good policy to discuss the comparative strengths of wastes from dairy products plants for fear of establishing possible limits. Some of the data gathered from several places are contained in Table II.

In order to determine the losses from one of Indiana's larger milk plants the owners have installed a Trebler sampler and weir box. Data have been accumulated over a long period of time on the flow and the volatile solids content of the waste. The average pounds of milk received at the plant are not available, but it is known that the low is not below 200,000 lb. per day and the high not much over 500,000 lb. per day. Table III shows the monthly averages of daily data.

Correcting the volatile constituent for the solids in the water supply that are lost on ignition, and using the volatile solids concentration of milk and a value of milk of $3.00 per hundred

TABLE II.—Dairy Plant Waste Characteristics

Place	Type of Plant	Total Solids (p.p.m.)	5-Day B.O.D. (p.p.m.)
Glen Karn, Ohio (66)	Cheese	1246	755
Nunda, N. Y. (1)	Receiving, creamery, powder	1421	706
Moravia, N. Y. (1)	Receiving	1141	509
Interlaken, N. Y. (1)	Receiving	4570	638
Peruton, N. Y. (1)	Receiving	659	453
Elba, N. Y. (1)	Receiving and powder	2407	485
Somerset, Pa. (105)	Creamery, condensery, powder, cottage cheese, etc.	797	545
New Bremen, Ohio (66)	Creamery, condensery, powder, ice cream mix	2422	1246
Purdue Dairy	Receiving, creamery, cheese	1291	548
Coldwater, Ohio (66)	Evaporated milk	2793	1291
St. Louis Dairy, Highland, Ill. (142)	Bottling	1521	440
Highland Dairy Farms, Highland, Ill. (142)	Creamery, cottage cheese	1510	1000
Indiana	Condensery	817	368

TABLE III.—Data on Wastes from an Indiana Condensery

Month	Ave. Waste Flow (g.p.d.)	Volatile Solids (p.p.m.)		
		Ave.	Min.	Max.
January	80,672	406	225	655
February	58,115	532	362	1407
March	57,565	605	337	3549
April	65,483	789	429	6824
May	109,367	466	219	704
June	133,350	582	268	1075

TABLE IV.—Calculated Daily Dollar Loss in an Indiana Condensery

Month	Dollars per Day		
	Average	Minimum	Maximum
January	$ 53.10	$22.70	$ 95.00
February	53.50	32.90	159.20
March	61.80	29.60	415.00
April	95.20	46.10	916.00
May	85.60	29.40	140.00
June	136.90	49.40	274.00

pounds, the waste losses from this plant when converted to dollars are rather startling, as shown in Table IV.

It is realized that the amounts indicated cannot all be recovered and that they are not all dollar losses to the milk company. The milk lost in washing milk cans is a loss to the farmer. The milk processer, however, must pay for the disposal of the organic solids lost in the waste waters. The excessive or unusual losses are certainly losses to the milk processer. A calculation of the average percentage loss from the data given shows that the plant being discussed had reasonably low percentage losses of milk solids. It is believed that if the farmer and milk processer were made to realize the economic value of the losses that they would act to reduce them.

Information obtained daily on flows and waste strength can be more than helpful to the engineer designing a waste treatment plant. Analysis of the data makes it possible for him to design an adequate plant to meet the requirements of the regulatory agencies and yet be as inexpensive as possible. The daily data for a 6-month period from the Indiana plant previously discussed have been considered as it might be used by a consulting engineer in arriving at adequate capacities for waste treatment units. Table V illustrates a method for analyzing the available data. It is realized that there are seasonal variations in the quantity of raw milk processed, and that data covering an entire year together with the future plans of the company should be considered in designing a treatment plant with adequate capacity.

It is obvious from the information in Table V that provision must be made to eliminate all spills of milk solids that are in excess of 30 per cent of the maximum average monthly day. It is probable that the daily average for each month should exclude some

TABLE V.—Analysis of Data from an Indiana Condensery

Month	Volatile Solids in Waste (lb. per day)	Number Days Volatile Solids Received Exceeded Monthly Average by Indicated Percentage			Number Days Volatile Solids Received Exceeded Maximum Monthly Average by Indicated Percentage		
		10%	20%	30%	10%	20%	30%
January	266	8	4	2	0	0	0
February	259	6	5	3	1	1	1
March	292	3	3	3	1	1	1
April	430	2	2	2	2	2	2
May	386	10	8	8	4	3	1
June	491	12	6	1	11	6	1

of the days when spills were apparent and where the spills materially affect the daily average. With provisions made to eliminate spills, the engineer should design a waste treatment plant to treat wastes 30 per cent in excess of the maximum daily average for the maximum month. The volatile solids can be converted into B.O.D. units, according to Bloodgood and Canham (35).

Levine, Soppeland, and Burke (113) state that a creamery waste differs markedly from ordinary sewage in many respects but particularly in that it contains carbohydrate lactose. If the character of milk wastes is so different from domestic sewage, it seems strange that Ruf and Warrick (162) reported finding the same organism forms in milk waste treatment filters that Lackey found most abundant in municipal sewage filters.

Barritt (34) says that "milk wastes contain varying amounts of fat, protein and sugar—all of which are found in domestic sewage—and are readily decomposed by bacteria. The proportion of sugar to protein is much higher than in sewage. . . . A high sugar content in relation to nitrogen retards the purification, requiring a longer time of contact, and the addition of sewage or ammonia would be helpful in the case of whey."

Kessener and Rudolfs (100) wrote: "It has been frequenty stated that it is practically impossible to treat dairy wastes by the activated sludge process. This would be true if quantities of milk-sugars were discharged. The growth of undesirable organisms would prevent efficient operation, and the organic acids produced would impair the activities of the desirable organisms."

The Massachusetts State Board of Health Report of 1898 (2) stated that milk wastes could be purified by methods similar to those employed in the purification of sewage (probably septic tanks and sand beds). The report noted an observation that nitrification was better when lactic acid bacteria were least numerous.

Treatment Experience

With this somewhat gloomy foreword on milk wastes as food for microscopic organisms there should perhaps be some hesitancy to investigate waste disposal methods that have been tried.

The experimental plant at Grove City, Pa., described by Phelps (153) consisted of a septic tank and two sand filters. The wastes treated were those produced in manufacturing butter, cottage cheese, and casein. Phelps recommended holding the waste in the septic tank for 12 hours and then discharging it to a sand filter. The data that he gave showed that the oxygen consumed of the waste could be reduced from 782 p.p.m. to 283 p.p.m. This is very significant reduction and, if the process could be controlled, could be very helpful in modern processes of treatment. The more recent investigations discussed in open meetings by Dr. Trebler on this subject do not seem to be available in the periodicals. The sand filters, that Phelps believed could be dosed at rates from 25,000 to 70,000 gal. per acre per day, did not stand the test of time.

Levine, Soppeland, and Burke (113) have stated that lactose which undergoes acid fermentation in a septic tank renders the waste extremly refractory to septic tank treatment. In a later bulletin (116) Levine says that the problem of purifying creamery wastes resolves itself into the development of a means of destroying milk sugar without acid production. Attempts have been made to neutralize the acid with lime, but such a procedure is probably about as practical as the adding of lime to a sewage sludge digestion tank. It is true that the lime neutralizes the acid but it does not promote the growth of the

flora that converts the acids into more inert compounds. Levine and associates (116) took a very definite stand on the use of anaerobic and aerobic processes for milk waste treatment. They condemned the septic processes and heartily approved the trickling filter. Ruf and Warrick (162), in their Wisconsin studies, approved the use of trickling filters in these words: "Properly designed and operated trickling filters, built of crushed rock, 1 to 2 inches in size, 6 to 8 feet in depth, and having a capacity of 80 cubic feet of rock per pound of five-day B.O.D. applied per 24 hours, will normally reduce the pollutional strength of the wastes 80 per cent or more." This is about 0.27 lb. of B.O.D. removed per cubic yard of stone. The 80 per cent removal of B.O.D. from a 600 p.p.m. waste results in an effluent of 120 p.p.m., which in many instances is not satisfactory for discharge into some streams.

Eldridge (62) does not favor the use of primary settling tanks for milk wastes because the character of the waste is such that very little can be removed by settling unless the acidity can be increased to the undesirable point where the casein will be precipitated.

Eldridge (71) writes that the Guggenheim biochemical process can be successfully used for the treatment of cheese factory wastes if the waste contains only cheese washings and only a very little whey. The upper value of B.O.D. for the influent to the plant seemed to be about 3,000 p.p.m. The effluent produced had a B.O.D. of 229 p.p.m., and this required the addition of 280 p.p.m. of lime and 56 p.p.m. of ferric chloride. The effluent from the Guggenheim plant at Glen Karn, according to Hatch and Bass (87), had a B.O.D. of 167 p.p.m. They believe that somewhat better results might have been obtained with technical supervision of the plant. Trebler (174) gave more credit to the plant at Glen Karn, stating that it would not handle all of the whey produced but would take about one-third of it and recover nicely in a day or two. The Guggenheim plant at Marshall, Ind., has been replaced by a high-rate trickling filter of novel design.

Montagna (143) states that the activated sludge plants of the H. W. Walker Co., Somerset, Pa., and the White Mountain Creamery Co., New Bremen, Ohio, produced average effluents below 10 p.p.m. B.O.D. A survey by the Ohio Department of Health of the New Bremen plant (87) gave the average effluent B.O.D. as 12 p.p.m. The Doe Run, Pa., plant of the Highland Dairy Products Co., reported by Mallory (131), yielded effluents of less than 4 p.p.m. B.O.D. The Mead Johnson and Co. plant at Zeeland, Mich., designed and reported on by Mallory (132), was said to produce an effluent with a B.O.D. of from 3 to 10 p.p.m. The activated sludge plant described by Kessener and Rudolfs (100) at Hamoir, Belgium, produced an effluent with a B.O.D. of 5.3 p.p.m. Levine, Burke, and Linton (116) say that purification of creamery wastes by activated sludge treatment will not produce a completely stable effluent, and the amount of air required will be considerable.

Eldridge (73) reports on the operation of high-rate trickling filters, and presents data from a plant at Perrinton, Mich., where a raw waste of 537 p.p.m. B.O.D. was reduced to 46 p.p.m. The Perrinton plant has a holding tank for about one-half of the daily flow. This permits a more even application of waste to the filter. A short detention period of 8 minutes in the secondary settling tank was reported to be undesirable. The report of Hatch and his associates (87) on the Coldwater, Ohio, plant of the Pet Milk Co., shows that a waste of 1,291 p.p.m. B.O.D. can be reduced to 6.4

p.p.m. by a high-rate filter. The Ohio River Committee Report (24) gives other illustrations of high-rate trickling filters which are treating milk wastes and producing effluents with slightly over 50 p.p.m. B.O.D.

Summary

The following processes of milk waste treatment have been reviewed briefly: (1) septic tanks and sand filters, (2) trickling filters, (3) Guggenheim process, (4) activated sludge, and (5) high-rate trickling filters. The brief discussion of each process given here would indicate that there seems to be no one entirely suitable process. It is not the intention of the writer to point out that any one process is more suited or less suited for the treatment of milk wastes.

It is apparent that difficulties are experienced with all types of plants. These difficulties may be in the form of (1) high construction costs, (2) high costs of operation and maintenance, (3) biological problems, and (4) chemical problems. None of the difficulties is impossible to overcome. It will take time and effort to accomplish the desired service. If continued effort is made to eliminate stream pollution by milk plants, progress will be made in overcoming all of the obstacles.

The training of personnel in milk plants will go far in eliminating waste to streams. Half-way measures will not do. One of the dairy products plants in Indiana was recently confronted with the disposal of a batch of spoiled product. The personnel knew that the waste would upset the company's waste treatment plant, so the spoiled product was hauled by tank truck and dumped into a stream where it promptly used up the oxygen and killed all of the fish in the stream. Unfortunately, the party responsible for the dumping failed to inquire where he might safely dispose of the waste.

The information presented on the Indiana condensed milk plant shows an average waste concentration which is reasonable. The calculated losses for this plant are unusually low except in a few instances. During the time covered by the data spills were apparently occurring. Possibly it is necessary to require milk products plants to be designed so that spills cannot get to the sewer system without authority of the management. Some industries are resorting to such regulations and construction.

Conclusions

1. The value of milk lost in dairy products plants is surprisingly high.
2. Spills of products in dairy plants must be eliminated if the wastes are to be treated in treatment facilities of economical size.
3. Milk wastes can be treated in suitable treatment plants designed with adequate capacity.
4. Decreased cost of construction and operation of milk waste treatment plants will result from further study of economical construction and increased purification per unit of plant volume.

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MILK WASTE DISPOSAL—A DISCUSSION *

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The dairy industry, faced with the waste disposal problem in plants of all types and sizes, has recently taken an important forward step in the organization of a Task Committee on Dairy Waste Disposal. This committee is made up of representatives of the Milk Industry Foundation, the National Cheese Institute, the Evaporated Milk Association, the American Dry Milk Institute, the Dairy Industries Supply Association and the American Butter Institute.

The objectives of the committee are five-fold:

1. To inform all branches of the dairy industry on ways and means of reducing dairy plant waste. This program is educational, and stresses the necessity of reducing plant waste to minimize the problem of waste disposal.
2. To initiate studies of equipment design and plant layout for the purpose of reducing waste.
3. To initiate studies for economical methods of waste utilization.
4. To educate dairy plant management on the importance of measuring and analyzing wastes.
5. To collect, evaluate and disseminate information regarding existing waste treament and the economics involved in such treatment.

The committee is stressing the importance of attention to the first four parts of the program before construction of a treatment plant. Careful conservation of wastes in the plant, and utilization of by-products, such as skim milk, whey and buttermilk, will materially reduce the treatment requirements and thus will result in extensive savings in fixed charges and operating costs for waste treatment. Design of treatment facilities without first instituting the highest degree of waste conservation and utilization in the plant represents an error in engineering judgment.

The committee's recommendations on dairy waste saving are given in a paper (1) presented at the annual convention of the Milk Industry Foundation on October 21, 1946, by William A. Dean, Jr., committee chairman. This report classifies dairy wastes as follows:

1. Wastes due to inefficient processing equipment, methods, or operation.
2. Waste of whey, buttermilk, skim milk, or other by-products.
3. Waste of spoiled products.
4. Waste due to rinsings and wash water.

Waste Prevention

In the first group of wastes can be listed definite items of equipment which will reduce waste strength. These suggestions cover all types of plants and so necessarily will not all apply to any one plant.

1. A straight-away can-washer of 10 to 16 cans per minute capacity should have at least three drain positions. Can-washers of lower capacity than 10 cans per minute should have a total of two extra can positions for draining. The first position of these three additional positions in the large can-washers should be a pre-rinse position, in which from 5 to 6 ounces of water is sprayed rapidly into the can immediately after the can comes to the first position. The remaining two positions are drain positions.

2. Electronic liquid level controllers to prevent overflowing of milk or dairy

* Extracted from paper presented at 22nd Annual Conference, Michigan Sewage Works Association, Jackson, May 14–16, 1947.

products from vats, tanks and coolers, and to prevent boiling over in vacuum pans.

3. Adequate temperature controls to prevent boiling over in hot wells and and freeze-ups on plate coolers.

4. All joints, packing glands and seals should be checked daily for leakage.

5. Foam should be kept out of the sewers. Excessive foaming can be due to air leaks in suction lines, splashing in tanks and use of old open-type separators.

6. Vacuum pans should be equipped to prevent entrainment of milk solids in the condenser water. Development of more positive entrainment separators would be desirable. Entrainment can cause losses as high as 1 per cent of the total milk processed.

7. Inadequate water supply to vacuum pans can cause a pressure drop which will increase temperatures in the pan. Then, if the pressure rises suddenly, a high instantaneous vacuum can be developed which can draw off a large volume of milk. A separate water line of adequate size should be run to the pans whenever possible.

Remarkable reductions in B.O.D. can be effected by instituting waste saving measures. In one plant, a waste saving program was instituted which reduced the B.O.D. from 260.5 lb. per day to 73.4 lb. a reduction of 72 per cent without replacement of any equipment.

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NATION-WIDE SANITATION SURVEY REPORT AVAILABLE

The report on the 1947 Public Health Service survey of nation-wide sanitation needs is now available in printed form.

The survey shows that the cost of needed water supply and waste disposal facilities is estimated at $7,834,581,000. More than 2 million persons, living in communities of 200 or more population, have no community water supply systems and 79 million have systems needing improvements. Less than 11 million live in communities for which no water supply improvements are scheduled. More than 6 million persons in towns and cities need new sewerage systems and 79 million need improvements to such systems.

In rural areas, more than 27 million people need new or improved water supplies and over 33 million have unsatisfactory sewage disposal systems.

To remedy this condition, the nation needs an additional 2.2 billion dollars worth of water works; 3.7 billion dollars of sewerage facilities; 166 million dollars of garbage facilities; and 1.6 billion dollars of all types of sanitation facilities for rural homes. The estimates are based on June, 1946, construction costs.

Almost 40 per cent of this needed construction is apparently at least in the planning stage. About 9 per cent of needed sewerage construction and 17 per cent of water supply systems are ready for construction.

Printed copies of the survey report are available from the Superintendent of Documents as Supplement No. 204 (Nation-wide Inventory of Sanitation needs) to the Public Health Reports, April 1948, at 15 cents each.

BIOCHEMICAL OXYGEN DEMAND OF SULFITE WASTE LIQUOR*

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Sulfite waste liquor (hereinafter designated SWL) is the spent liquor from the process of manufacturing sulfite wood pulp. Sulfite waste liquor is produced by cooking wood chips in an acid-resistant digester at elevated temperatures and pressures. Calcium bisulfite is circulated through the chips during the 8 or 10 hours required to dissolve the lignin or cementitious material in the wood. The contents of the digester are then blown by its own pressure against the wall of the blow-pit to separate the individual wood fibers.

The pulp is washed with a spray of process water, thus diluting the concentrated digester liquor to several times its original volume. The resulting "blow-liquor" drains through perforations in the stainless steel floor of the blow-pit and discharges to the sewer. This discussion deals with the undiluted digester liquor, which contains about 12 per cent total solids. It is a complex material having a high B.O.D., the determination of which requires some modification of standard procedures.

The reason for discussing the B.O.D. of this waste is two-fold. In the first place, it is of interest in the Pacific Northwest and certain other areas in the United States because it places a much greater oxygen demand on the receiving waters than that received from municipal sewage. Secondly, it contains interfering substances that complicate the B.O.D. test, so that its investigation is particularly helpful in giving a better understanding of this test, its techniques and difficulties, than can be obtained by testing simpler substances.

It is important to be able to measure the B.O.D. of SWL accurately since this test is generally accepted by sanitary engineers as the best indication of the strength of sewage or industrial wastes. It is similarly accepted for measuring the relative difficulty in disposing of the waste material, and for measuring the load which it places on the receiving waters into which it is discharged. It is necessary, therefore, that it be a true measure of these factors and that it be susceptible of being duplicated, or checked, with reasonable accuracy by different investigators. The purpose of the paper is to present a general statement of the problems involved in the determination of the B.O.D. of SWL, with a summary of the conclusions arrived at by the authors. The test techniques being employed in the present research are also described, and some of the factors which affect the B.O.D. of SWL are discussed.

Several excellent studies of the B.O.D. of SWL have presented considerable data on the various problems encountered in making this test. The Green Bay Report (1) has described in detail a comprehensive study of the factors involved, and of the rate of oxygen demand of some of the components of SWL, such as SO_2 and lignin. Sawyer (2) has discussed the

* Presented at Twentieth Annual Meeting, Federation of Sewage Works Associations, San Francisco, Calif., July 24, 1947.

selection of dilution of waters for the B.O.D. test. Ruchhoft's report (3) on a comparative study of dilution waters has thrown further light on this knotty problem, while other writers have also contributed to the knowledge of the B.O.D. test, its techniques, and the numerous problems encountered.

General Statement of Problem

Information concerning the B.O.D. of domestic sewage has accumulated for so many years that the B.O.D. of its various constituents is generally known. Its three major components are the carbonaceous, nitrogenous, and fatty materials. The carbonaceous materials break down during the first stage of incubation (10 to 20 days at 20° C.), while the nitrogenous matter is attacked during the second stage. The fats, while interfering with certain steps in sewage treatment, are digested with the sludge, but do not appreciably affect the B.O.D. determination of the sewage sample. The 5-day B.O.D., therefore, is principally a measure of the carbonaceous materials.

In the case of SWL, the situation is less simple because of the greater complexity of the liquor. The B.O.D. is a composite of the demands of the liquor's various components, each having its peculiar rate of breakdown. These materials include free and combined SO_2, volatile acids, alcohols, acetone, furfural, sugars, and lignin. More is known concerning the rate of breakdown, or B.O.D., of the sugars than of the other components, but even this information is far from being complete. In fact, the various tests for sugars in a waste such as SWL are unsatisfactory to the extent that they do not differentiate between sugars and other substances which reduce copper in alkaline solutions.

Lignin breaks down much more slowly than do the sugars, and it has usually been assumed that it would not have an appreciable effect on the 5-day or even the 20-day B.O.D. The 5-day B.O.D. of SO_2 was reported in the Green Bay Report (p. 212) to be about 400 p.p.m., which would be a negligible fraction of the total B.O.D. of the SWL. Data concerning the B.O.D. of the other materials listed are lacking. It is obvious, therefore, that in discussing the B.O.D. of SWL, one

TABLE I.—Theoretical Oxygen Demand of Sulfite Waste Liquor (11)*

Component	Sample One				Sample Two				Computed as
	Grams per Liter	Total Solids (%)	Computed Oxygen Demand		Grams per Liter	Total Solids (%)	Computed Oxygen Demand		
			P.P.M.	Per Cent of Total B.O.D.			P.P.M.	Per Cent of Total B.O.D.	
Formic acid	0.63	0.53	219	0.15	1.19	0.86	413	0.25	HCOOH
Acetic acid	4.68	3.95	4,990	3.40	5.22	3.77	5,560	3.42	CH_3COOH
Methyl alcohol	1.26	1.07	1,880	1.27	0.72	0.52	1,079	0.66	CH_3OH
Ethyl alcohol	0.171	0.14	353	0.24	0.230	0.17	439	0.27	C_2H_5OH
Acetone	0.134	0.11	296	0.20	0.099	0.07	218	0.13	CH_3COCH_3
Furfural	0.285	0.24	475	0.32	0.244	0.18	406	0.25	$C_5H_4O_2$
Pentose	2.55	2.16	2,728	1.86	3.37	2.43	3,600	2.22	$C_5H_{10}O_5$
Hexose	17.5	14.8	18,770	12.80	17.1	12.3	18,240	11.20	$C_6H_{12}O_6$
Lignin	61.5	52.2	117,000	79.5	69.6	50.2	132,500	81.60	$C_{42}H_{42}O_{14}$
Misc.	29.3	24.8	—	—	40.93	29.5	—	—	—
Total	118.0	100.0	146,711	100.0	138.7	100.0	162,461	100.0	—

* Benson-Partansky test data. *Note:* Ca and S have been omitted from this analysis.

is involved in an extremely complex problem made up of components concerning which information is either entirely lacking or very meager.

Theoretical Oxygen Demand

A consideration of the theoretical amounts of oxygen that would be required to oxidize completely these various components will help to throw some light on their relative importance. Very few reasonably complete analyses of the liquor are available in the literature, but Tables I to IV give some conception of its composition.

In Table I (11) are included the *theoretical* oxygen demands for the complete oxidation of the various component materials. While these data have no bearing on the actual B.O.D. of the liquor, they give some idea of the magnitude of the oxygen requirements involved. From Table I, the theoretical demand of the lignin is seen to be about 80 per cent of the total demand of the liquor. The sugars account for some 15 per cent, while acetic acid averages about 3 per cent.

TABLE II.—B.O.D. of Various Components of SWL (12)

Component	Per Cent of Actual B.O.D.
Immediate chemical demand (SO_2)	11
Sugars	63
Acetic acid	12
Alcohol	1
Lignin, furfural, etc.	13

Table II gives the approximate contributions of the various factors to the *actual* 5-day B.O.D. as reported by William R. Barber, Crown Zellerbach Corporation, Camas, Washington. This table shows a shift of sugars to the place of first importance, with SO_2, acetic acid, and lignin competing for second place. The SO_2 is in a separate category in that a large fraction of its demand on the dissolved oxygen of the receiving waters is made in a matter of a few minutes, whereas the other demands develop slowly and biochemically.

In Table III, the composition of SWL from a typical pulp plant is expressed in terms of its principal component elements. These represent average values of the monthly composites for 10- and 14-month periods, respectively.

TABLE III.—Average Composition of Digester and Blow-Pit Liquor at a Typical Pulp Plant

Components	Digester Liquor[1] (p.p.m.)	Blow-Pit Liquor[2] (p.p.m.)
Total solids (T.S.)	111,100	38,700
Volatile solids (V.S.)	101,000	34,000
Ash	10,100	4,700
Ca	3,990	1,550
Total SO_4	31,200	8,620
B.O.D. (20-day)	42,900	—

[1] 10-month average. [2] 14-month average.

The data in Table IV are reported in an article, "Effect of Waste Sulfite Liquor on Soil Properties and Plant Growth," by J. B. Spulink, R. E. Stephenson, W. E. Caldwell, and W. B. Ballen, *Soil Science*, **49**, 37 (January, 1940).

TABLE IV.—Relationship of Major Components of SWL

Component	Per Cent of Total Solids (Bone Dry Basis)
Lignin	51.6
Sugars	16.9
Sulfur	9.15
Calcium	4.5

The theoretical oxygen requirements computed on the basis of total solids given in this table would be 134,700 p.p.m. per 100,000 p.p.m. total solids.

Variations in Concentration of Waste as Discharged from Mill

It should be pointed out that there is no generally accepted method for re-

porting the B.O.D. of SWL. Values given in the literature vary from 400 to 50,000 p.p.m. without mention of the fact that the lower value represents blow-pit liquor which has been diluted by many times its own volume of water, while the higher value represents digester liquor, or the concentrated waste as it comes from the digester before being mixed with process water in the blow-pit. In the process of discharging a digester at the completion of a cook, the contents are blown, by the pressure in the digester, into the blow-pit where the digester liquor is washed out of the pulp. The liquid waste leaving the blow-pit is called "blow-pit liquor" and is usually diluted to several times its original volume. The latter varies widely in character throughout the day, based on the cooking schedule, as shown in Figure 1.

When one reads in the Green Bay Report (4) that the B.O.D. of SWL is 50,000 p.p.m. at 20 days, while the Ohio River Pollution Survey (5) reports a figure of 443 p.p.m., Imhoff and Fair (6) give 400 p.p.m., and Eldridge (7) reports 11,100 p.p.m., much unnecessary confusion is produced. Obviously, wide variations in dilution have occurred in the sample of liquor referred to in these different cases. In the Green Bay Report, it was recommended that this difficulty be resolved by reporting B.O.D. in terms of a liquor having 100,000 p.p.m. total solids. There might be some advantage in expressing the B.O.D. in terms of a liquor having 100,000 p.p.m. volatile solids (solids lost on ignition) rather than total solids, since the former gives a measure of the organic solids which are the source of most of the B.O.D.

Present Knowledge of the B.O.D. of SWL

A brief summary is presented of the findings of various investigators concerning the different factors involved in the B.O.D. determination on SWL.

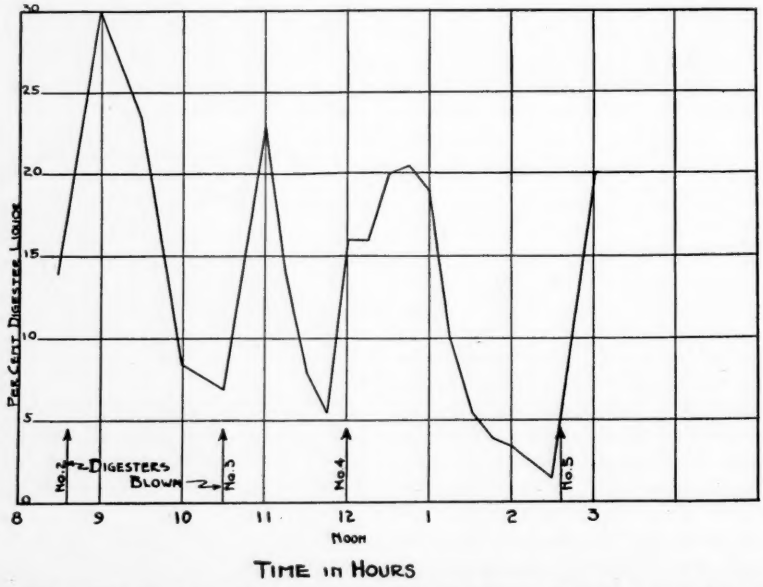

FIGURE 1.—Hourly fluctuations in concentration of digester liquor in waste discharged from pulp mill.

Dilution Waters

The type of dilution water used is of primary importance. In the Green Bay Report the three dilution waters used were: (a) unpolluted East River water, aged approximately 2 weeks; (b) Lea and Nichols' fortified and seeded dilution water; (c) unseeded bicarbonate dilution water.

For one sample of SWL, these waters gave 20-day B.O.D. results of 35,000 p.p.m., 31,600 p.p.m., and 16,000 p.p.m., respectively. River water normally gives higher values than synthetic dilution waters, and is to be preferred where the information desired is the probable effect produced by discharging the liquor into the stream. Synthetic waters are necessary if the data are to be compared with the results from other research.

Sawyer and Williamson (8) found both the Lea and Nichols' supplemented bicarbonate water and the supplemented Formula C water suitable for determining the B.O.D. of carbohydrate wastes, the former being superior. Ruchhoft (9) recommends the latter as the better after an extensive series of tests.

Seeding

The method of seeding used in the Green Bay studies, and in most of the other work done prior to the present research, consisted of the standard method of using 1 ml. of settled sewage or 10 ml. of river water per liter of distilled water.

Sawyer (8) found seeding "a minor but necessary factor in the B.O.D. test. Natural seed in the dilution water may be sufficient, but a small inoculation with fresh sewage is a reasonable procedure."

Effect of Free and Combined SO_2

The Green Bay Report (p. 212) gives the oxygen demand of SO_2 as 400 p.p.m. at 5 days, or approximately one per cent of the B.O.D. of the liquor. It is held to be biochemical in nature. In Table II, Barber gives the demand of SO_2 as chemical in origin, and places its value as 11 per cent of the total B.O.D. While part of this difference was caused by a difference in the two liquors tested, part of it was undoubtedly caused by the different test procedures used.

Effect of Dilution

All investigators have found that the B.O.D. of SWL increases with dilution. It has been suggested that this may be a matter of mineral content, and that the B.O.D. increases up to the point where the minerals added become sufficient to support the requisite bacterial growth. Beyond that point, which is far from definite, additional dilution is not advantageous. High dilutions magnify errors from slight variations in the titre, so there is a limit to the dilution that can be used with safety.

Miscellaneous

Very little is known concerning the nature of lignin. The Green Bay Report states that "Calcium ligno sulfite * is apparently colloidal in nature, being unable to pass through a semipermeable membrane." This statement has been questioned by other investigators.

The same report also states that the carbohydrates consist of pentoses and hexoses, of which only the latter are fermentable. The combined SO_2 is thought to be coupled onto the lignin, as is also the case with nearly all of the CaO present. Nutrients such as nitrogen and phosphorus are lacking or insufficient in the SWL, and should be added except where river water used for dilution supplies adequate amounts.

* The authors prefer the designation "calcium lignosulfonate," which indicates the organic nature of the compound.

TABLE V.—Composition of Dilution Waters Used

Dilution Water	P.P.M.
Standard bicarbonate:	
$NaHCO_3$	300
Supplemented bicarbonate:	
$(NH_4)_2SO_4$	2.50
$Ca_3(PO_4)_2$	0.01
$MgSO_4$	0.01
KH_2PO_4	0.10
$NaHCO_3$	300
Formula C:	
$FeCl_3$	0.06
$CaCl_2$	30.00
$MgSO_4$	14.70
$KNaHPO_4$	
KH_2PO_4	47.50
Supplemented formula C:	
$FeCl_3$	0.06
$CaCl_2$	30.00
$MgSO_4$	14.70
$KNaHPO_4$	
KH_2PO_4	47.50
$(NH_4)_2SO_4$	1.87

The Present Research

During the past several years, studies of the various factors discussed above have been made by the authors. The following conclusions were reached from these studies.

Dilution Waters

In view of the contradictory reports in the literature regarding the best type of dilution water to use in B.O.D. determinations on industrial wastes, it was decided to investigate the problem using SWL as the substrate. Four standard dilution waters were used as follows: standard bicarbonate water, supplemented bicarbonate water, Formula C water, and supplemented Formula C water. The composition of these dilution waters appears in Table V.

Aerated distilled water was used as a control, with the soil suspension hereinafter described as the inoculum. In one series, Table VI, a sample of freshly stripped * SWL was set up in duplicate with each dilution water, and a single sample of raw SWL with the distilled and supplemented waters only. A second series using stripped SWL is also given in the table. It is seen that supplemented Formula C water gave consistently higher results.

* Stripped of the free and part of the loosely combined SO_2 by passing the liquor through a bubble plate column, or one filled with Raschig rings, counter-current to a flow of steam. The SO_2 removed in the steam can be used again in the cooking liquor.

TABLE VI.—Comparison of Dilution Waters in Determining the B.O.D. of SWL

Sample	Dilution Water	5-Day B.O.D. (p.p.m.)		
		Sample 1	Sample 2	Average
Stripped SWL (2/7/46)	Distilled	13,800	13,400	13,600
	Standard bicarbonate	14,400	12,100	13,300
	Formula C	11,500	10,100	10,800
	Supplemented bicarbonate	23,200	23,800	23,500
	Supplemented formula C	30,200	31,800	31,000
Raw SWL (2/7/46)	Distilled	14,300	—	—
	Supplemented bicarbonate	28,700	—	—
	Supplemented formula C	33,200	—	—
Stripped SWL (2/22/46)	Distilled	20,500	26,900	23,200
	Standard bicarbonate	25,600	21,800	23,700
	Formula C	22,300	21,900	22,100
	Supplemented bicarbonate	33,000	28,400	30,700
	Supplemented formula C	39,700	37,200	38,450

It has been stated earlier in this paper that higher B.O.D. values are obtained using river water for dilution purposes. It appears logical to conclude that when SWL is discharged into a stream or tidal water, organisms will develop over a period of time which will be more effective in attacking the liquor than is indicated by laboratory B.O.D. tests. There is justification, therefore, for using that dilution water which gives the highest results, since the portion of the total theoretical oxygen demand that will be handled by receiving waters will doubtless be greater than that obtained in any laboratory test.

Aged and aerated river water, without seeding, is preferred for dilution purposes to synthetic waters where the problem studied is of local interest and comparisons with other research are not important. It has the advantage of simplicity and requires less work. In the present research preference was given the dilution water and method of seeding recommended herein because they gave higher results with SWL than did any synthetic water with other seeding, and also made it possible to compare results with those obtained by other investigators.

Seeding

Standard methods of seeding dilution waters have not proved satisfactory in the authors' experience. While it would appear logical to assume that organisms which can break down the carbohydrates in sewage should be able to attack carbohydrates in SWL in a satisfactory manner, this waste is so complex and concentrated as to apparently interfere with their action. The authors' experience appears to justify the conclusion that sewage organisms are not the most efficient to use with SWL.

Some earlier research led the senior author to believe that standard methods of seeding were less satisfactory when used for B.O.D. tests on concentrated SWL than on partly stabilized liquor. He later used soil organisms as a satisfactory seed in some studies of seepage of the liquor from storage ponds. In the present research, therefore, it was decided to use soil organisms as one method of seeding, using the technique described later in this paper. This method has given somewhat higher B.O.D. values than have sewage organisms, though the latter gave quite consistent results. Some evidence of seasonal variation in activity of soil organisms, however, was indicated by monthly averages, the maximum variations being as much as 20 to 30 per cent.

One important reason for securing adequate seeding is to guarantee immediate activity of the organisms in breaking down the material being tested and thus prevent lag.

In the Green Bay Reports (4), B.O.D. values of 50,000 p.p.m. at 20 days were obtained with unpolluted aged river water for dilution purposes. The soil organisms and minerals present in the river water gave higher B.O.D. values than those obtained with unseeded bicarbonate water or supplemented bicarbonate water seeded with stale or aged sewage.

In the earlier research, micro-organisms were taken from acid soils or areas adjacent to local pulp mills where SWL had been percolating through the soil for a considerable period. Later it was found, however, that average garden soil contains organisms that are equally satisfactory for seeding purposes.

An attempt to use seeding organisms isolated from experimental high-rate trickling filters gave interesting results. Such a low B.O.D. was obtained when used on the filter effluents that it was apparent that these organisms had done their utmost as the liquor passed through the filter and, therefore, could accomplish little further digestion of the effluent, while affording adequate seed for the influ-

ent. Such seeding would show too high a B.O.D. removal, as indicated by other methods of seeding. This experience gives rise to the question of whether sewage seeding also may indicate too high a B.O.D. removal for the secondary stage of sewage treatment plants.

Effect of Free and Combined SO_2

This experience has differed from that of the Wisconsin studies in that the SO_2 has a greater as well as an immediate effect on the oxygen demand of SWL. If dilutions are prepared for the B.O.D. determination, the dissolved oxygen test of the dilution indicates that an appreciable amount of oxygen demand has already been exerted during the few minutes required for its preparation.

The free and combined SO_2, and possibly other substances present in the liquor, possess large capacities for iodine absorption, and thus give a large apparent oxygen demand by the uncorrected Winkler test, which varies with the dilution. Its value approximates 10 per cent of the 20-day B.O.D. The alkaline-hypochlorite modification has not proved satisfactory, in the authors' experience, in eliminating the errors due to these iodine-absorbing substances. The results obtained with its use were inconsistent, and the test is too complicated for confident use as a routine technique. A study of various methods of correcting for sulfites has been in progress for some time. From this study, it appears that the true chemical demand may not exceed 10 to 20 per cent of the uncorrected values. Carrying the test to completion as quickly as possible increases its accuracy, and one may need to resort to gasometric or polarographic methods for obtaining satisfactory determinations.

The SO_2 is probably linked to the sugars rather than the lignin since most of the sulfur passes a dyalizing membrane which retains the lignin.

Lignin

Whether calcium lignosulfonate can be broken down biochemically to any appreciable extent is still debatable. Methoxyl determinations have failed to show definite correlations between B.O.D. and methoxyl removals, but do indicate some breakdown in the lignin. Doubt has been thrown upon these tests, however, by others using the Warburg apparatus, in which our micro-organisms in pure culture have failed to break down calcium lignosulfonate separated from the liquor by a dializing membrane. The data at present available are thus conflicting and inconclusive in character, but possibly a slight effect of the lignin is indicated in the 5-day B.O.D. determination. Some researchers have considered the calcium lignosulfonate as colloidal in nature, but more recent information concerning its behavior favors the theory that it is in true solution (13). It is a complex substance, made up of molecules having weights of from 1,000 to possibly 20,000, which is smaller than those colloids familiar to sanitary engineers. Neither does it exhibit characteristics usually associated by the latter with colloidal substances. The statement that SWL is or is not colloidal is not of particular concern. Greatest interest is in the coagulation and settling characteristics usually associated with colloidal materials.

Reducing Substances

Tests on reducing substances carried out in parallel with the B.O.D. studies gave more consistent results than did the B.O.D. work, probably because varying degrees of autolysis affected the latter but not the former. The copper-reducing substances include hexoses and pentoses, both of which are oxidized, though in varying degrees, by the organisms used in these experiments. While it is claimed that pentoses are not fermentable, some can

be oxidized and, therefore, they do affect the B.O.D. Zylose, for example, has been oxidized in this laboratory by pure cultures, indicating that the pentoses are undoubtedly affecting the B.O.D. values.

The B.O.D.-Time Relationship

A study of B.O.D. determinations on monthly composites of the daily discharge of digester liquor taken continuously at a local pulp mill over a 10-month period indicates that the 5-day, 20° C. B.O.D. is about 67 per cent of the 20-day value. In two other extended test series this ratio was 62.6 and 64.4 per cent, respectively. It is thus apparent that the average oxidation rates of SWL are similar to those of sewage. This appears to be relatively independent of methods of seeding, nutrient used, and dilution ratios employed, since both sewage and soil-seeding were used in these tests; nitrogen was used with and without phosphorus, and dilutions varied from 1 to 10,000 up to 1 to 70,000. The *total* B.O.D. in 5 or 20 days, however, does vary widely with the seeding, type of nutrient, and dilution water used, and with the dilution ratio employed.

Procedure for B.O.D. Determination

From time to time during the past two years, the B.O.D. procedure used in this laboratory has been modified in an attempt to develop a method which would be relatively simple, give reproducible results, and accurately measure the oxdizable material present in the sample. The following procedure is the one which is now used for routine analyses in connection with studies on the disposal of SWL.

Apparatus

A carboy of convenient size for the number of tests to be run, graduated to facilitate its use, is employed in the preparation of the dilution water. A graduated separatory funnel (1 to 2 liter capacity) is used for preparing the desired dilution of the SWL sample. The carboy and separatory funnel are connected by means of rubber and glass tubing in such a way that the dilution water may be drawn into B.O.D. bottles from the carboy, or be siphoned into the separatory funnel, mixed with the sample, and discharged into the B.O.D. bottles, without the entrainment of air (Figure 2). A small

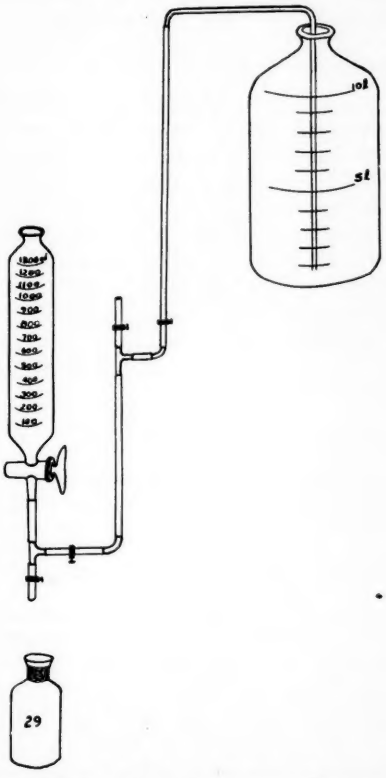

FIGURE 2.—B.O.D. dilution apparatus.

variable-speed mechanical stirrer has been found to be essential in producing satisfactory mixing of the nutrients and seed with the dilution water in the carboy, and of the SWL with the water in the separatory funnel. For 1 to 10,000 dilutions, only 0.1 ml. of SWL is required per liter of dilution water, and adequate mixing can

be secured only by mechanical stirring. Preparing the dilution in two steps has not been found preferable and requires an additional operation with more complex apparatus. Lack of adequate mixing is believed to explain the inconsistent results frequently obtained in making B.O.D. determinations on SWL. Apparatus of the type described here greatly facilitates the making of the test and decreases the time requirement.

Soil Suspension

One part of garden soil is mixed thoroughly with two parts of water (by weight) in a large jar provided with a screw cap. After shaking in a shaking machine for about 10 min., the mixture is filtered through filter paper until a clear or only slightly turbid filtrate is obtained. This "soil suspension" may be stored in the refrigerator over a period of several weeks, and does not give too high a blank.

Dilution Water

A modification of Ruchhoft's supplemented Formula C dilution water is used.

Dissolved Oxygen Determination

The Rideal-Stewart or permanganate modification of the Winkler method was used for some time to counteract the effect of the nitrites produced in the B.O.D. bottle from the nitrogen added as nutrient. But neither this nor the alkaline-hypochlorite method have proved satisfactory with SWL in this laboratory. More consistent results have been obtained by avoiding delays in the determination of the end-point than by the above methods. The authors' experience and conclusions with reference to the Winkler test and its modifications have been discussed previously in this paper. Research to determine more satisfactory methods has been in progress in this laboratory; the results are being prepared for publication.

Test Procedure

The dilution water is made up in the large carboy by adding the nutrients to aerated distilled water that has been stored overnight in the 20° C. incubator to prevent the formation of bubbles in the B.O.D. bottles. This is seeded by adding 5 ml. of soil suspension per liter of dilution water, and mixing thoroughly with a mechanical stirrer. Bottles which are to be used for the determination of the B.O.D. of the dilution water blanks are filled directly from the carboy.

The SWL samples are then diluted and *thoroughly* mixed with the seeded dilution water in the separatory funnel, using a mechanical stirrer but with care not to increase the dissolved oxygen of the dilution. It is then discharged into the bottles through a tube with outlet submerged.

The excess diluted SWL is withdrawn and the separatory funnel is rinsed with distilled water before reuse. A dilution ratio of from 1:10,000 to 1:15,000 is used with the concentrated digester liquor, with dilutions on treated effluents decreased approximately in proportion to their relative strengths. A definite dilution ratio should be established on any given project, since the B.O.D. varies with the dilution employed with the methods presently used.

Three bottles are filled with each mixture, one being used for the determination of the initial dissolved oxygen content while two are incubated for 5 or 20 days at 20° C., and the dissolved oxygen content again determined. If the incubation is long enough for the water to evaporate from the funnel-shaped mouth of the bottles, they should be placed in a water bath (requiring a slightly higher incubator temperature) or covered by inverted cups filled with water. These

cups are readily made from glass tubing of suitable diameter to clear the flared bottle mouth, sealed at one end and rounded. The cup is filled and the bottle inverted, its mouth inserted into the cup, and then righted.

The B.O.D. is then computed in the usual way by multiplying the dissolved oxygen per 200 ml. sample by the reciprocal of the dilution ratio.

Operators should check each other within 5 to 10 per cent.

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FEDERAL POLLUTION BILL SIGNED

On June 30, 1948, President Truman signed the Barkley-Taft Anti-Stream Pollution Bill (S.418), thereby climaxing a 51-year old fight for a Federal clean-stream law. Anti-pollution bills first were introduced in the 55th Congress in 1897, and at least one such bill has been introduced in each succeeding congressional session. Signing of the bill came on the same day the Ohio River Valley Sanitation Compact was formally signed by the eight compact states at Cincinnati, Ohio.

The law authorizes appropriations of $22.5 million annually for 5 years for loans to states for the construction of pollution abatement works. Individual loans may not exceed one-third of the cost of a project or $250,000, whichever amount is smaller. Also authorized is an appropriation of $1 million annually for 5 years for grants to states for financing the preparation of engineering plans and specifications for pollution abatement works. An additional $1 million annually is authorized for 5 years for grants to states for surveys and studies of water pollution prevention and control.

In declaring the pollution of interstate waterways a nuisance, the law makes possible federal court action against those responsible for such pollution. Authorization is granted the Surgeon General of the Public Health Service to undertake necessary stream pollution control surveys and research.

Stream Pollution

UNIQUE SAMPLER FOR DEEP-WATER SURVEYS

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During 1929, in the course of a sanitary survey of Lake Superior in the vicinity of Duluth, Minn., and Superior, Wis., the Minnesota Department of Health had occasion to collect bacteriological water samples from the lake at depths ranging up to 150 ft. or more. Various types of sampling devices were available for collection of samples near the surface, but none of these was adaptable for use at the depths encountered in this survey. Consequently, a different principle was used in designing and developing a sampler which appeared to fulfill the requirements of the problem. This sampler operated satisfactorily throughout the summer of 1929, but until the present time, there has been no further need of it. Now that need for its use has again arisen, and since no reference to a device of this type has been seen, it appears appropriate to discuss its features and to point out the reasons that other types of samlers were rejected for deep sampling.

A sampler which is frequently used is one in which the stopper is drawn from the bottle at the desired depth and replaced by a spring mechanism. This sampler may be used satisfactorily at relatively shallow depths to which it can be quickly lowered. At greater depths, however, it is impossible to withdraw the glass stopper because of the differential in pressure. (Actually, in experiments at a depth of 125 ft., some bottles which had not had the stoppers loosened were found to be half full when brought to the surface, and others were crushed.) In addition, the supporting cord and the pullcord are certain to become twisted together, rendering the pullcord useless.

The volume-displacement types of samplers were rejected because they might be filled before the desired depth was reached, and also because they might retain contaminating material from a higher level. The latter objection also applies to the Kemmerer sampler, which consists of a brass cylinder with two rubber plugs which are held away from the open ends until a tripping mechanism is actuated by a messenger lowered from the surface.

Design of Sampler

In designing the sampler used in this work, it was decided that the device should be made to open and close at the sampling depth to assure a reliable sample representing the indicated depth. To accomplish this without using a complicated timing mechanism or double trigger system, it was decided, with some apprehension, to employ an electromagnet actuated by a source of current in the boat.

The body of the sampler is made of a section of 3-in. cast iron pipe with a cut-down companion flange on one end, and with the other end closed by means of a plate welded in place. A ⅛-in. copper tube which provides the inlet to the sampler is soldered into a hole in the plate. The cast iron bottom plate is held in place by means of four bolts (three would be sufficient) and wing nuts. To simplify placing and removal of the bottom, the bolts

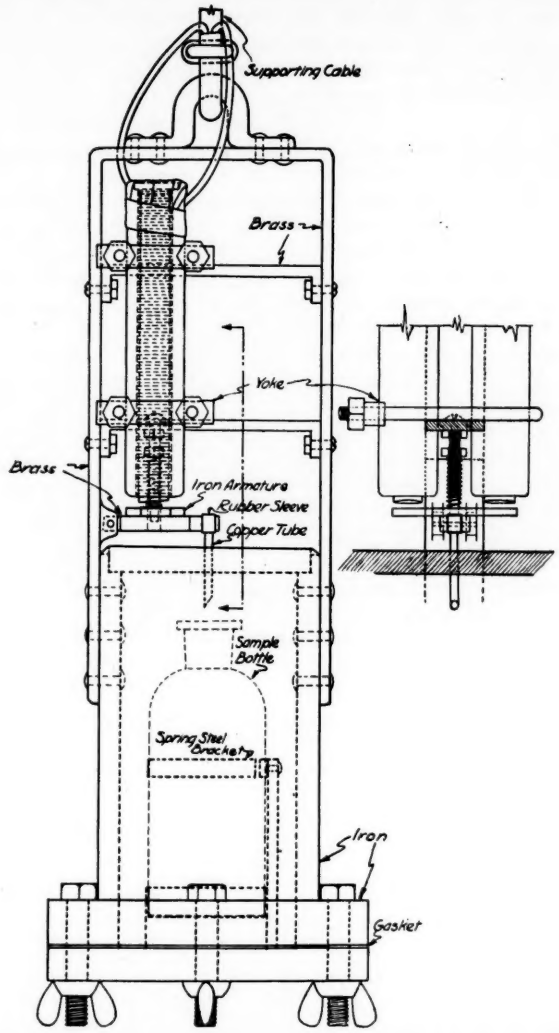

FIGURE 1.—Sectional diagram of sampler designed for deep-water surveys.

should be welded to the body. The stand for the sample bottle is also of cast iron, secured to the bottom plate.

The upper part of the device, which is constructed of brass to avoid magnetizing the entire sampler, serves as a handle in addition to supporting the mechanism. The magnet was constructed of parts from two Model "T" Ford coils, encased in thick rubber tubing and heavily taped and shellacked. The two crossmembers of the frame are shaped to fit the magnet elements, which are held in place by means of U bolts. The valve consists of a small piece of rubber tubing stretched over the end of the lever arm and held against the inlet tube by the adjustable spring between the coils. This spring is only strong enough to

hold the rubber securely against the tube, and is easily overcome by the magnet. A small iron plate fastened to the lever arm serves as an armature to lift the arm.

The two-wire rubber cable serves to raise and lower the sampler as well as to carry the current to the magnet. A cable 200 ft. long was used, and was wound around a windlass in the boat with the ends of the two wires exposed for connection to the 12-volt storage battery. These connections were made by means of spring clamps.

Operation

As the sampler is lowered, the increasing water pressure aids the spring in keeping the valve closed, the pressure within the sampler being that of the atmosphere. When the valve is opened at the desired depth, water rushes in, filling the bottle and compressing the air until pressure equilibrium is reached. When the sampler is being raised to the surface, the inside pressure forces air out of the inlet so that atmospheric pressure is again approximated. This is the reason for terminating the inlet tube above the mouth of the bottle. Otherwise water would be forced from the bottle by the air pressure.

In designing the body of the sampler, it was necessary to provide sufficient air volume to permit compression to a volume which would permit the bottle to be filled with water at depths just beyond the reach of the surface sampler. At the same time, the sample bottle was placed high enough in the body so that there would be sufficient air volume at the greatest depths to be encountered to prevent the top of the bottle from becoming submerged, thus avoiding contamination of the sample from the sampler.

The weight of the sampler insures its maintaining a nearly vertical position in lowering and raising, so that water outside of the bottle will not overflow the mouth of the bottle. Provision can be made for disinfecting the inlet tube between samples by the use of a chlorine solution or a small blowtorch. In the latter case, it would probably be necessary to use a material with a higher melting point than solder to secure the inlet tube in place.

THE OPERATOR'S CORNER

CONDUCTED BY S. C. MARTIN

ENCOURAGING PLANT VISITATION

In the last Operator's Corner the suggestion was advanced that plants and operators both would profit from more frequent visits by the taxpayers. To accomplish this, planned action by the sewage works operator is essential. He must relate the taxpayers' personal interest to the sewage plant in concrete and practical ways. Here are a few examples of sewage works men who have done this.

Robert Dick, Elmhurst, Ill., succeeded admirably in attracting favorable visitor attention by flooding a low spot adjacent to the plant and developing a skating area for the community. Benches were also provided. Grading and seeding a large area adjoining the service building produced a playground, which, with the help of local service clubs, was soon provided with playground equipment.

David Backmeyer, Marion, Ind., embellished the skating pond idea by mounting flood lights and loudspeakers on the service building roof so that skating on the adjacent lagoon could be enjoyed at night—with music.

At Clinton, Ill., crab apples are turned from a liability to an asset by making them available to the townsfolk. At another plant, worms flushed from the trickling filter are collected for the local fishermen who prize them highly as bait and who are encouraged to use the plant river-frontage for fishing. Several operators have developed picnic grounds with tables, ovens, playground equipment, etc., at or adjacent to their plants, and thereby have attracted many visitors. At Champaign, Ill., a comfortable cabin for the use of youth organizations is maintained in a large wooded area adjoining the sewage works.

Many plant operators have long promoted visits by school classes as a means of increasing public interest in the sewage treatment works. This is a method of stimulating interest which could be much more widely and profitably employed. The sludge stock pile, so often a problem for sewage works men, can be turned into a valuable tool for attracting townsfolk to the plant if it is used with imagination and initiative. No operator has yet exploited the full possibilities of digested sludge as a good-will builder.

With interest in organic fertilizers increasing by leaps and bounds, particularly among flower lovers, a small amount of time invested in building a good-size compost pile would pay rich dividends in visitors attracted to the plant each spring by an offer of free compost for plant seedbed and plotting purposes.

A few fruit trees set out on the plant grounds could be developed into a community charity project, with service clubs or religious groups cooperating in the harvest and distribution of the fruit. For the little work involved in annual spraying and pruning, the favorable attention of the entire community could be focused on the sewage plant and its personnel each fall.

These are but a few of the ways sewage works visitation can be encouraged. Any sewage works "hermit" can become a "host" by mixing industry and ingenuity with common sense, and adding a dash of imagination.

S. C. M.

SALARY TRENDS OF SEWER MAINTENANCE AND SEWAGE TREATMENT PLANT PERSONNEL *

By Reuben F. Brown

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The Committee on Salaries and Wages for Sewer Maintenance and Sewage Treatment Plant Personnel was appointed by the president of the California Sewage Works Association in February, 1947. The committee was directed to develop recommendations for a standard wage scale for all personnel employed in the maintenance and operation of a sewage works system. This assignment has required extensive study and research in order to present a satisfactory tabulation of salary rates whereby administrative officials, management, and labor might be able to sit down in good faith and stabilize wages in a community, regardless of size, according to the local prevailing industrial and construction wage scales.

Basic Factors Considered in Salary Recommendations

Budget Requirements

In the analysis of basic data for the recommendation of a wage and salary schedule, certain factors were considered. Salaries must meet the requirements of an economically planned budget. They must, however, be adequate and satisfactory to the majority of employees responsible for the maintenance and operation of a sewage works system.

Position Responsibility

It was recognized that salary scales should be based upon the degree of responsibility placed upon maintenance and operating personnel, and that they should be based upon educational and experience requirements. Licensing of sewage plant operators, when established upon these standards, was considered as a basis for measuring ability and responsibility. Also considered was the fact that classification and certification of sewage plant operators are closely related to the compensation or salary structure.

Certification and licensing of operators have been urged by the various sewage works associations in order to improve operation methods; to obtain personnel fulfilling the requirements as to education, training, and experience; to obtain recognition of ability in the community for a position having some professional status; and to provide the security of steady employment with opportunity for advancement. Certification, however, is of little value unless an adequate salary is paid, commensurate with the responsibility and requirements of similar positions in the community.

Certification Plans Inadequate for Position Classsifications

Certification of sewage works operators has not taken into consideration all of the different types of skilled personnel necessary for plant operation. In general, certification plans have been set up on the basis of classes or grades in an attempt to define sewage works duties and responsibilities. In some parts of the country classification of operators has been made by type of plant, or by class of plant on the basis of population served or quantity of sewage flow.

Fixed responsibilities and duties will vary in different communities. In

* Presented at the 20th Annual Meeting, Federation of Sewage Works Associations, San Francisco, Calif.; July 21–24, 1947.

spite of this, certification plans have not given sufficient consideration to personnel responsible for the maintenance and repair of sewer systems. It is now recognized that certain wastes discharged at the upper end of a sewer system are the cause for high operation costs and overloaded treatment plants. Skilled, trained personnel necessary for efficient underground sewer operation should be considered in any salary schedule for a sewage works system. Good sewer maintenace is as important as skilled plant operation.

Adjustments Necessary

A street maintenance roller man or equipment operator may receive as much in wages as the chief operator of a sewage treatment plant; one, the operator of an $8,000 piece of equipment, the other, the operator of a million dollar plant. Compensation should be based upon responsibility. Correct position evaluation providing equitable compensation provisions will improve employee morale and stabilize public service employment in all communities.

Salary Benefits in Public Service

Public employees in sanitary engineering work in general are career men. Year around employment is essential to retain such experienced personnel. In any salary standard for public employees consideration must be given to the value of benefits received through governmental employment. One of the greatest benefits of public service is steady employment, which is insured by civil service for all employees and qualifying examinations for all positions.

Other benefits of value are: a pension system; vacation and sick leave with pay; a 40-hour week; straight pay for overtime with, in some cities, extra pay for hazardous work (deep sewer excavation or repairs, etc.), night work, and work under obnoxious conditions; a federal loan and savings plan; group life insurance; a medical plan; and in-service training for advancement and efficiency. When all stated benefits are received, salaries of governmental employees should be at least 10 per cent less than outside or prevailing wages. Thus the difference in wages is equalized, and the government employee earns the benefits received.

The salary trends for municipal officials and employees have been rising for the last 5 years to meet the increased cost of living and added responsibilities due to population growth and service demands. This increase has been from 10 to 40 per cent, depending on the position and the location and size of the city.

City and County Salary and Wage Surveys

To establish a basis for pay increases several cities have made surveys of the prevailing wage rates in their local areas. Positions and wage rates of comparable work in private industry and local governmental units have been studied, and comparisons made with wage rates in selected cities of similar size and type.

This method of position classification establishes a comprehensive and valid pay plan. By its use existing pay structures are made consistent, and the question of subsequent pay increases becomes a matter of meeting rising living costs. The salary survey is made annually. Periodic reviews of personnel classification are made to reflect any changes in position duties and responsibilities.

Such an annual salary survey was made by the city of Los Angeles, Bureau of Budgets and Efficiency, in January and February of 1947. No other city has made exactly the same kind of survey. The survey required the services of 17 trained persons for 10 weeks. The positions of over 12,000 city employees were investigated. In addition, salary informa-

TABLE I.—Standardized Salary Schedule for Sewer Maintenance and Sewage Treatment Plant Personnel

Civil Engr. Salary Grade	Schedule No.	Monthly Rates					Daily Rates	Hourly Rates
		1	2	3	4	5		
	8	$101	105	110	115	120	$ 5.04	$ .63
	9	105	110	115	120	125	5.28	.66
	10	110	115	120	125	131	5.52	.69
	11	115	120	125	131	137	5.76	.72
	12	120	125	131	137	143	6.00	.75
	13	125	131	137	143	150	6.32	.79
	14	131	137	143	150	157	6.56	.82
	15	137	143	150	157	165	6.88	.86
	16	143	150	157	165	173	7.20	.90
	17	150	157	165	173	181	7.60	.95
	18	157	165	173	181	190	7.92	.99
	19	165	173	181	190	200	8.32	1.04
	20	173	181	190	200	211	8.72	1.09
	21	181	190	200	211	221	9.20	1.15
	22	190	200	211	221	233	9.68	1.21
	23	200	211	221	233	246	10.16	1.27
	24	211	221	233	246	259	10.72	1.34
	25	221	233	246	259	273	11.28	1.41
I	26	233	246	259	273	288	11.92	1.49
	27	246	259	273	288	303	12.56	1.57
	28	259	273	288	303	319	13.28	1.66
	29	273	288	303	319	337	13.92	1.74
II	30	288	303	319	337	355	14.64	1.83
	31	303	319	337	355	375	15.52	1.94
	32	319	337	355	375	395	16.32	2.04
	33	337	355	375	395	417	17.28	2.16
III	34	355	375	395	417	440	18.16	2.27
	35	375	395	417	440	464	19.20	2.40
	36	395	417	440	464	489	20.24	2.53
IV	37	417	440	464	489	516	21.36	2.67
	38	440	464	489	516	545	22.48	2.81
	39	464	489	516	545	575	23.76	2.97
V	40	489	516	545	575	608	25.04	3.13
	41	516	545	575	608	641	26.40	3.30
	42	545	575	608	641	677	27.92	3.49
	43	575	608	641	677	715	29.44	3.68
VI	44	608	641	677	715	755	31.12	3.89
	45	641	677	715	755	797	32.88	4.11
	46	677	715	755	797	842	34.72	4.34
VII	47	715	755	797	842	889	36.64	4.58
	48	755	797	842	889	940	38.72	4.84
	49	797	842	889	940	992	40.88	5.11
VIII	50	842	889	940	992	1048	43.20	5.40

tion was secured from 480 private firms representing every major industry with jobs comparable to those in local governmental agencies. Of 364,623 employees in these private firms, 81,216 were located with jobs comparable to the 84 city bench mark positions. Strong emphasis was placed on accurate definition of positions. Job titles were used only for initial consideration. Allowance was made for housing, meals, etc., when furnished. Final acceptance of specific position designations depended upon job description agreement.

The result of this salary survey has been an excellent budget report on salary requirements, and an adjustment of underpaid and out-of-line positions. Engineering employee positions were placed in line with the current recommendations of the American Society of Civil Engineers, as set up for annual salary ranges from Grade I to Grade IX. These positions also are in agreement with the report of the American Association of State Highway Officials on the need of salary adjustments. The salary survey also made it possible for the responsible officials making the survey report to back up the salary requests with honest facts.

Standardized Salary Schedule

Table I is a standardized salary schedule for various monthly, daily, and hourly rates of pay. Each pay range carries a salary schedule number. The table indicates the five-step yearly advancement within each salary range. Every employee automatically receives this increase each year until the fifth step is reached, unless his service rating indicates his work is unsatisfactory. Salary schedule numbers in Tables III and IV, used to indicate rate of pay for sewer maintenance and treatment plant personnel, refer to this table.

Table II is the proposed salary schedule as recommended by the American Society of Civil Engineers. It shows the new grade classifications, based on responsibility, education, and experience.

Salary Trends by Position Titles

Table III shows the position title, salary schedule, and salary range for the various personnel used in maintaining and operating a large sewage works system. The salary schedules indicated have been based on current wage trends, salary surveys, and reports used in research for basic data. The titles of positions listed will not

TABLE II.—American Society of Civil Engineers' Proposed Salary Schedule for Engineers

Salary Rates Proposed by the A.S.C.E. in 1944		Current Federal Employee Wage Rate		Current Recommendation of the A.S.C.E.	
Grade*	Rate	Grade*	Rate	Grade*	Rate
I	$1,980–2,460	—	—	—	—
II	2,460–3,000	P-1	$ 2,645–3,400	I	$ 2,700–3,400
III	3,000–3,600	P-2	3,400–4,150	II	3,400–4,200
IV	3,600–4,200	P-3	4,150–4,900	III	4,200–5,100
V	4,200–5,160	P-4	4,900–5,900	IV	5,100–6,100
VI	5,280–6,480	P-5	5,900–7,100	V	6,100–7,250
VII	6,720–7,920	P-6	7,100–8,180	VI	7,250–8,600
VIII	8,160–9,360	P-7	8,180–9,970	VII	8,600–10,350
IX	9,600 and up	P-8	9,970–10,000	VIII	10,350–12,600
—	—	P-9	10,000 and up	IX	12,600 and up

* Grades indicate the classification of positions according to supervision, training, duties, experience, leadership, and independent judgment required.

all be the same as the job-description title used in other places. Publication of detailed position-classification job descriptions for sanitary engineering and sewage works employees would assist in establishing uniform wages for comparable positions in all cities.

The positions listed in Table III represent the trained, skilled personnel required for the maintenance and operation of a metropolitan sewage works system.

Salary Trends in Cities According to Size

As cities reduce in size fewer employees are required until the administrative official responsible for the

TABLE III.—Sewer Maintenance and Sewage Treatment Plant Personnel Positions Classed as to Title and Responsibility *

Title of Position	Salary Schedule	Monthly Salary Range ($)	Engineer's Salary Grade
Common Laborer	18	157–190	
Sewer Maintenance Laborer	19	165–200	
Guard and Watchman	20	173–211	
Maintenance and Construction Helper	21	181–221	
Sewage Sample Taker	21	181–221	
Plant Attendant	21	181–221	
Warehouseman	21	181–221	
Gardener-Caretaker	21	181–221	
Clerk-Typist	21	181–221	
Clerk-Stenographer	22	190–233	
Senior Gardener, Supervisor	23	200–246	
Truck Operator	23	200–246	
Plant Helpers (screen and grit chamber, aeration and sludge tanks, etc.)	23	200–246	
Machinist, Welder, Blacksmith, Electrician, Carpenter, and Mechanical Helper	24	211–259	
Senior Clerk-Stenographer	24	211–259	
Sewage Laboratory Aid	24	211–259	
Mechanical Repairman	25	221–273	
Compressor Operator	25	221–273	
Store Keeper-Supervisor	25	221–273	
Electric Pumping Plant Operator	25	221–273	
Sewage Plant Operator	25	221–273	
Sewer Maintenance Crew Foreman	26	233–288	I
Supervising Sewage Plant Operator	26	233–288	I
Engineering Aid	26	233–288	I
Plant Engineer (gas, diesel)	26	233–288	I
Equipment Mechanic	26	233–288	I
Equipment Operator (electrical, gas engine, locomotive, etc.)	27	246–303	I
Carpenter, Painter, Sheet Metal Worker, Cement Finisher, Machinist	27	246–303	I

Note: One step advancement in salary schedule for any position where regular working conditions are different than that called for by the classified position. Night work, obnoxious or filthy work, hazardous work—one step.

* Wage trends according to current salary surveys, 6–30–47.

TABLE III.—Continued

Title of Position	Salary Schedule	Monthly Salary Range ($)	Engineer's Salary Grade
Chlorine Equipment Operator	27	246–303	I
Industrial Waste Inspectors	27	246–303	I
Electrician, Plumber, Pipe Fitter, Electric Mechanic	28	259–319	I
Sewer Maintenance Dist. Foreman	29	273–337	I
Sewer Maintenance Construction Foreman	29	273–337	I
Principal Clerk	29	273–337	I
Working Foreman of Carpenters, Electricians, Machinists, Painters, Plant Operators, etc.	30	288–355	II
Electrical Foreman	31	303–375	II
Chief Sewage Disposal Plant Operator	31	303–375	II
Engineer-Draftsman	31	303–375	II
Equipment Repair Foreman	32	319–395	II
Bacteriologist-Laboratory Asst.	33	337–417	II
Civil Engineer Assistant	33	337–417	II
General Foreman (maintenance sewer pipe line, equipment; plant repair operations)	34	355–440	III
Principal Construction Inspection Engineer	35	375–464	III
Civil Engineer Associate	36	395–489	III
Industrial Waste Engineer	36	395–489	III
Bacteriologist, Sewage Testing Engineer	37	417–516	IV
Civil Engineer	38	440–545	IV
Engineer of Sewage Disposal Plants	38	440–545	IV
Assistant Division Head, Asst. Supt. of Sewer Maintenance and Plant Operation	39	464–575	V
Division Head, Supt. Engr. of Sewer Maintenance and Plant Operation	41	516–641	VI
Bureau Engineer, Disposal of Wastes	45	641–797	VII
Manager-Director-Engineer, Maintenance and Sanitation, Public Works Department	50	842–1048	VIII

maintenance and operation of the sewage works may be the city manager, or a specialized sanitary consulting engineer employed on a retainer basis. Sewer, refuse, and street operations may be administered jointly by one individual.

Table IV gives the results of a study made to observe the salary trend for sewage works employees in cities of varying size and sewage flow. It is based on reported salaries paid administrative officials. The salary schedule number is from Table I. The engineer's grade number is from Table II. The study shows reduced salaries for engineers as cities decrease in size, or until the administrative or responsible engineering official will be directing only a few highly skilled and

TABLE IV.—Comparison of Salary Range of Sanitary Engineering Employee's Group. Yearly Salary Trends for Administrative Officials in Class of Cities According to Size and Sewage Flow

Class of Cities According to Size	500,000 to 3,000,000			250,000 to 500,000			100,000 to 250,000			50,000 to 100,000			25,000 to 50,000			10,000 to 25,000			5,000 to 10,000			5,000 or Under		
Estimate of Sewage Flow (m.g.d.)	50 to 300			20 to 50			8 to 20			4 to 8			2 to 4			0.8 to 2.0			0.4 to 0.8			0.05 to 0.4		
Key Administrative Position Effecting Classification Breakdown	Job Classification		Salary Range ($)	Job Classification		Salary Range ($)	Job Classification		Salary Range ($)	Job Classification		Salary Range ($)	Job Classification		Salary Range ($)	Job Classification		Salary Range ($)	Job Classification		Salary Range ($)	Job Classification		Salary Range ($)
	Proposed[1] Schedule	A.S.C.E.[2] Grade		Proposed[1] Schedule	A.S.C.E.[2] Grade		Proposed[1] Schedule	A.S.C.E.[2] Grade		Proposed[1] Schedule	A.S.C.E.[2] Grade		Proposed[1] Schedule	A.S.C.E.[2] Grade		Proposed[1] Schedule	A.S.C.E.[2] Grade		Proposed[1] Schedule	A.S.C.E.[2] Grade		Proposed[1] Schedule	A.S.C.E.[2] Grade	
1. City Administration—																								
Mayors	60	9	16,000	50	8	10,000	47	7	8,580	45	6	7,692	40	5	5,846	38	4	5,280	34	3	4,260	30	2	3,456
City Managers	60	9	25,000	50	8	15,000	47	7	10,668	45	6	9,654	40	5	7,296	38	4	6,540	34	3	5,280	30	2	4,260
2. Department Administration—City Engineer, City Attorney, General Manager, Fire Chief, Police Chief, Controller	50	8 to 9	10,000 to 15,000	47	7 to 8	8,500 to 10,668	40 to 45	5 to 6	5,868 to 9,564	40	5	5,868 to 7,296	38	4	5,280 to 6,540	34	3	4,260 to 5,280	30	2	3,456 to 4,260	28	2	3,108 to 3,828
3. Bureau Administration—City Engineers, Directors, Managers, City Clerks	47	7 to 8	8,580 to 10,668	40 to 45	5 to 6	5,868 to 9,564	37	4	5,004 to 6,192	34	3	4,260 to 5,280	34	3	4,260 to 5,280	29	2	3,276 to 4,044	28	2	3,108 to 3,828	26	2	2,796 to 3,451
4. Division Administration—Engineer of Design, Chief Construction Inspector, General Superintendent	40 to 45	5 to 6	5,868 to 9,546	37	4	5,004 to 6,192	34	3	4,260 to 5,280	29	2	3,276 to 4,044	27	1 to 2	2,952 to 3,626	25	1	2,652 to 3,276	23	1	2,400 to 2,952	23	1	2,400 to 2,952
5. Section Administration—Civil Engineer, Plant Engineer, Assoc. Engineer, General Foreman, Equipment Repair Foreman	34 to 38	3 to 4	4,260 to 6,540	30 to 33	2 to 3	3,456 to 5,004	29	2	3,276 to 4,044	27	2	2,922 to 3,636	26	1	2,796 to 3,451	23	1	2,400 to 2,952	21	0	2,172 to 2,652	21	0	2,172 to 2,652
6. Operations Administration—Supervisors, Engineering Assistants, Foreman, Operators	30 to 33	2 to 3	3,456 to 5,004	30	2	3,456 to 4,260	27	2	2,952 to 3,636	25	1	2,652 to 3,276	23	1	2,400 to 2,952	21	0	2,172 to 2,652	19	0	1,980 to 2,400	18	0	1,884 to 2,280
7. Crew and Gang Supervisors-Working Foreman, Operators, Engineering Aid, Maintenance Man	23 to 26	1 to 2	2,400 to 3,451	23 to 25	1	2,400 to 3,276	21 to 24	1	2,172 to 3,108	23	0	2,400 to 2,952	21	0	2,172 to 2,652	19	0	1,980 to 2,652	18	0	1,884 to 2,280	18	0	1,884 to 2,280

[1] Salary schedule number from Table I.
[2] Engineer's salary grade from Table II.

experienced laborers in the maintenance of a sewer system and/or the operation of a sewage treatment works.

By using Tables III and IV it is possible to establish a satisfactory standardized salary basis for sewage works personnel in all communities.

Salary Survey Requirements

In setting wage standards for municipal employees, honesty and fairness must be the policy. Wages should be equal to wages paid in private industry. Favoritism should never be practiced. Advancement should be by examination, ability, and years of experience. In this way it is possible to obtain and retain the highly technical, skilled operators and maintenance men necessary for the modern mechanized sewage works system.

Wage scales change according to duties, responsibilities, experience and required knowledge, and the number and type of employees under the direction of the various supervising administrative officials. A salary schedule which permits advancement from the lowest bracket to the highest will engender efficiency and high morale. There should be a difference of from two to three salary schedules among administrative officials. Administrative employees issuing orders and giving directions should always be in a higher salary bracket than those receiving the orders.

By analyzing work performed in different locations and comparing the requirements of such work with the positions listed in Table III, a standard salary schedule may be worked out for different cities. The grade-rating for engineers in Table III compares with the pay classifications of the American Society of Civil Engineers.

Employees should be classed according to positions listed. An employee must work over 50 per cent of his time at a trade to be given the title and corresponding salary schedule of that trade—plumber, pipe fitter, mechanic, etc.

Recommendations

As a result of facts obtained for presentation of this salary and wage report, the following recommendations are made:

1. That professional sewage works organizations should promote standardized classifications of positions according to duties and responsibilities of sewage works personnel in comparison to like work and like positions in other types of work.

2. That a standard plan of operation be worked out as to the average number of employees required to operate different types and sizes of sewage works. Consideration should also be given to the skilled trade positions required for the maintenance and operation of such works.

3. That the terms "maintenance man" and "operator" indicate an employee who through training, education, and experience is able to perform satisfactorily a variety of tasks. For example, an employee who is able to lay pipe; excavate and timber a trench; operate a pump, electric generator, or compressor; drive a truck; rod and clean sewers; use electric or air operated tools; use and handle small tools; fit and thread pipe; and act as helper or oiler on machinery is a valuable man when there is not enough work for one man all of the time on any one of these jobs. There should be adequate compensation for such versatile personnel.

4. That a yearly sewage plant operation certificate be issued by the state department of health for satisfactory plant performance. Certain basic engineering employees' positions will be equal in duties and responsibility in all types of sewage treatment plants. Such a certificate should indicate the efficiency of both men and equipment. It would not affect the permit now given by the state health department

for authority to discharge sewage into the receiving waters.

5. That a public relations program is essential for the establishment and efficient utilization of a properly adjusted salary schedule. The public should be informed as to the operation of the sewage works system. Sewage works reports and records should be standardized so that they can be used intelligently by administrative officials in a planned public relations program.

6. That the sewage works associations encourage a planned in-service training program for sewage works employees. Upon completion of training a certificate should be issued indicating the hours of training instruction received and the amount of such instruction retained, as demonstrated by examination covering duties designated by title of position of each trainee. Such training certificates of qualification by position should be issued by the state department of health.

7. That salaries paid sanitary engineers and skilled sewage works operators and maintenance men be equal to the prevailing wage scale in the community paid by private industry and construction agencies.

Conclusions

Salary and wages play an important part in the industrial productivity and economic life of a community. A definite fixed salary schedule is impossible. As supply and demand fluctuate with the purchasing power of the dollar, so a salary wage schedule must be adjustable according to prevailing wages in a community. An annual survey of prevailing wages and business trends will give a satisfactory basis for salary adjustment between employer and employee.

Practical on-the-job in-service training for every employee, from the lowest paid to the highest, will provide that self-esteem and freedom of self-expression necessary to the happiness of the individual through pride in his work. Such a program, sponsored by sewage works organizations and state health departments, would be of lasting benefit to every community.

All of the requirements, including adequate and equitable salaries, necessary to employ effectively a standardized salary schedule should be substantiated with written facts. Well-defined methods of operation together with clearly designated work duties for all positions are basic for a beginning in salary adjustment and standardization.

State and regional sewage works associations by means of a planned program of position classification, by the licensing of operators, by the distribution of manuals of sewage works operation and maintenance practices, and by close cooperation with active state health departments should assist in keeping standardized salaries equal to prevailing wage scales in all communities.

This salary and wage report is not an attempt to standardize salaries by collective action or to regiment a fixed salary for a fixed job. It is an attempt to prevent the waste, inefficiency, and confusion which results from the improper classification of positions by administrative officials, and the resulting discontent and dissatisfaction among employees which always ensues. It is not an attempt to gain security for sewage works employees except as security is obtained through ability to work and produce and, thus, fulfill the duty requirements of a designated position.

When experienced sanitary engineers are offered salaries less than those paid union tradesmen, when skilled sewage works men receive salaries equivalent to the wages of construction laborers, when city councils and administrative officials neglect to

apportion sufficient funds for repair, operation, and replacement of sewage works, something is wrong!

That "something is wrong" should challenge all sewage works associations, engineering groups, equipment industries, state and local health departments, and the entire personnel of the sewage works field to find the cause and correct the wrong.

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THE SMALL PLANT LABORATORY*

BY C. E. BRITT

Chemist, Plaskon Division, Libby Owens Ford

This paper is not especially technical. On the contrary, it is a collection of thoughts and ideas on the function of the sewage works laboratory and its relation to other phases of plant operation. It is a reflection of the author's interest in laboratories in general, of his 5 years within the confines of a sewage treatment plant, and of his experiences with hydrogen sulfide, sludge, filter flies, grease, bar screens, and all of the other things that are a part of sewage treatment.

*Presented at the 21st Annual Meeting, Ohio Conference on Sewage Treatment; Columbus, Ohio; October 3, 1947.

Definition of an Operator

One of the first things learned about sewage treatment was the correctness of the following definition of a sewage plant operator: a sewage plant operator is one who is versed in the art of sewage treatment, chemical engineering, hydraulics, public relations, and lawn mowing. This definition applies especially well to small plant operators, those with plants having a flow of up to one million gallons per day.

Herbert O. Johnson, of the Belgrave Sewer District, Great Neck, N. Y., gave this description of the small plant

operator (1): "The small plant operator must of necessity be a versatile and composite type of individual. He must be an electrician, pipefitter, machinist, gardener, and book-keeper with a leaning toward practical sanitary engineering and chemistry. He should have a generous amount of ingenuity, adaptability and diplomacy in his make-up and a large amount of conscientiousness. In addition to this he must have a tough stomach and a willingness to perform hard labor incident to tank and grit chamber cleaning, clearing of pipe line stoppages and sludge cake removal."

This is a large order, but many operators are filling the bill with great credit to themselves. Such men under slightly different circumstances might have become chemists and engineers. This makes it difficult to explain the suspicion that sometimes exists between technical and nontechnical personnel. After all, both are interested in producing a satisfactory effluent. To the uninitiated such common terms as bar screen, Imhoff tank, and trickling filter are highly technical. It is the responsibility of those who have had formal technical training to pass it along to the man at the sludge pump when the need or opportunity arises.

Laboratory Importance

Of course, the attention given to laboratory work is going to depend upon the size of the plant. This is a way of saying that it depends upon the number of gallons of sewage treated per day. However, the importance of laboratory work to a given plant also depends upon other factors, such as the nature of peak loads and trade wastes, and the plant's proximity to populated areas. Operators of large and medium size plants must rely upon laboratory results to a greater extent than the small plant operators to know how things are going. Thus, specially trained personnel and increased laboratory facilities are a necessity for larger plants and are not just embellishments made possible by a larger budget.

For the small plants, under the designation of laboratory are included all observations incident to plant operation, whether the observations came out of a test tube or not. Was there a peculiar odor about the influent today? Does the effluent look especially good or bad today? Were any fish seen in the receiving stream? How many pails of refuse were carried from the bar screen? These and many other observations that every operator could list with no difficulty at all give an indication of the operating characteristics of each plant.

Laboratory Records

For convenience, consider at this point a few reasons for keeping a record of laboratory and plant observations. These reasons apply equally well to large and small plants. First of all, plant records provide an indication of whether or not a plant is doing what it was designed to do and whether or not an operator is doing what he was hired to do. The records that go each month to the Department of Health are a representation that all is well or that a little help is needed.

In this matter of records there is no substitute for absolute honesty. Plant records are something of an insurance policy against the payment of claims by municipalities for pollution of the receiving stream. Equally important, plant records should help an operator understand the moods of a plant, indicating approaching difficulties and possible cures.

Laboratory Tests

In addition to the observations of a rather general type, also to be considered is the examination of sewage samples taken at appropriate stations throughout the plant. This examination divides itself into a consideration of the physical properties of sewage—

temperature, color, odor, etc.—and that of the more purely chemical tests that are used as measures of plant loading and efficiency. The more common tests are: settleable and filterable solids, dissolved oxygen, biochemical oxygen demand, chlorine demand and residual chlorine, solids and ash in raw and digested sludge, nitrogen balance, and gas analysis.

Obviously, the small plant employing one or two operators should not be expected to use these aids to the same extent as the larger plants. It is the author's opinion that little in the way of practical plant operation would be gained by it. Perhaps even the most meager testing program represents a challenge. Sewage plant operation requires healthy individuals and should never be regarded as a haven for the infirmed. A healthy person welcomes a challenge.

Aids for the Operator

There are several avenues of assistance open to the small plant operator. These are: the state department of health, the supervising engineer, books and periodicals, the local organization of sewage treatment plant operators, short courses, and factory standardized reagents.

A number of laboratory supply firms supply the ready-mixed solutions needed for the common determinations, such as B.O.D. Incidentally, this is one method of hiring outside help. Another method would be to employ the local high school chemistry teacher to prepare the solutions or even to run the more difficult or specialized analyses.

The author has had the opportunity of watching the growth of the local sewage conference idea in Ohio, beginning with the Northwestern Ohio Sewage Conference, just 10 years ago. It is a commendable movement and each operator should avail himself of this opportunity. By this means he can visit other plants, talk shop, and hear worth-while discussions on topics of interest to all plant operators.

Some state universities provide short courses on water and sewage treatment. Perhaps this state group can be instrumental in the development of such a course in Ohio.

There are a number of useful books and periodicals available for sewage works men. A few of these are: Standard Methods for the Examination of Water and Sewage (2); Laboratory Manual of Water and Sewage Analysis, by Theroux, Eldridge, and Mallman (3); *Sewage Works Journal* (4); *Sewage Works Engineering* (5); *Water and Sewage Works* (6); and American Sewerage Practice, Vol. III, by Metcalf and Eddy (7). Standard Methods for the Examination of Water and Sewage has recently been revised. Its information is much improved and it is easier to read.

Supervising Engineer's Role

The supervising engineer is usually the only person on the staff of the small treatment plant having technical training. His responsibilities are many and varied. Indeed, he is as complicated a mixture as the small plant operator so aptly described by Mr. Johnson. There must be times when he feels a little insecure and truly in the same boat as the operator. Perhaps many supervising engineers will disagree; but it is the author's contention that they should be a source of technical and practical information easily available to the small plant operator. Among other things, the supervisory engineer should instruct the operator concerning emergency measures. There is enough contrariness in all mankind that the supervising engineer cannot afford to neglect his personal relationships. They should be based on something more substantial than back slapping.

The supervising engineer cannot possibly be a specialist in all of the many activities of a sewage treatment

plant. There are times when he, too, can use a little help. Undoubtedly there are times when he should use the assistance of a trained chemist. The state department of health in several states is supplying some assistance of this kind. For example, one of the papers presented earlier on this program (8) was prepared by a state health department chemist. This information thus becomes available to the small plant operator with his limited facilities.

Small Plant Research

There is one other item of an educational nature that should be mentioned briefly. It is quite visionary and perhaps should be approached with some hesitation. Each sewage plant, from the largest to the smallest, has benefited from the research and mistakes of others. Accordingly, each plant, even the very smallest, should pay off this debt in some way. Sewage works men are experienced in the ways of getting things done and a way should be found for each small plant to contribute to a research program on small plant problems. Such a program might be undertaken by engineers of the state departments of health, or it might be turned over to a nongovernmental research organization.

Although every small plant has the responsibility of contributing to a research program, it is not a primary responsibility of the small plant operator. His laboratory work and records should tell the story of his plant and assist him in its day-to-day operation. To do this, each small plant operator should sit down with his supervising engineer and decide what tests are necessary. There is a lack of reality if the routine procedures are more elaborate or accurate than necessary to satisfactorily operate the plant and provide records on the nature of the effluent and receiving stream that would make a case in court. This is the minimum. If time and facilities are available to do more than this, by all means use them.

Importance of Sampling

Any chemical analysis, whether of sewage or pig iron, proceeds in several natural steps: sampling, physical examination, chemical examination, expression of results, and interpretation. All of the methods of quantitative chemical analysis are based on the assumption that the constituents of an unknown are present in the same proportion in the small sample analyzed as in the much larger volume from which the sample was taken. To make this a reality in practical situations requires considerable ingenuity. Sampling methods are usually a source of arguments at sewage works operators' meetings. One should realize that an analysis is no more reliable than the sampling, and that it is impossible to fully evaluate a set of data without knowing how the samples were taken. For his own protection, every operator should make the method of taking and storing samples a part of the records.

The physical examination of samples provides information on such things as temperature, color, and odor. A list of the more common chemical procedures has already been given.

Expression of Analysis Results

The results of a sewage analysis are usually expressed as parts per million by weight. This is an expression of intensity or concentration. This intensity factor in p.p.m. multipled by millions of pounds of sewage treated gives a quantity factor. This is a weighted result and furnishes information such as the pounds of B.O.D. removed in a given time. This is the same type of thing that is done when a daily wage is multiplied by the number of days worked in a year to obtain the annual earnings. Other examples of intensity factors are temperature, pH, and force. The corresponding

quantity factors are heat, normality, and work.

In interpreting laboratory results, ask questions such as these: Would the results stand up in court? Is the plant doing as well as it should? What extenuating circumstances were there? How can plant operation be improved next month?

Summary

To summarize briefly, this paper was presented as a collection of ideas and thoughts applicable to the sewage treatment plant laboratory with emphasis on the laboratory work of plants treating less than one million gallons per day. Reasons for laboratory records, approaches to self enlightenment, and something of the philosophy of laboratory work were presented. Many of the points mentioned in briefest of manner could be enlarged upon and discussed at length. This enlargement is left to the reader for his discussions and musings at the sludge pump.

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INTERESTING EXTRACTS FROM OPERATION REPORTS

"All roads worth taking lead uphill."
—*Grantland Rice*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Sixteenth Annual Report of the Elgin (Illinois) Sanitary District Sewage Treatment Plant for the Year Ending May 1, 1946

BY F. E. JOHNSON, *District Superintendent*

The report is a brief outline of the activities and work that have been carried out at the sewage treatment plant and pumping stations during the fiscal year May 1, 1945, to May 1, 1946.

Description of District

The Sanitary District of Elgin is a municipal corporation operating under the Illinois Sanitary District Act of 1917 and embracing an area of 5,320

acres. As of 1946 the district population was 35,000.

Sewage Treatment Works Changes

The treatment plant was designed to afford complete treatment for a sewage flow of 3.3 m.g.d. The plant, consisting of a grit chamber, four Imhoff tanks, one and one-half acres of trickling filter beds, two Dorr secondary settling tanks, sludge pump house, and office-laboratory building, was constructed at a cost of $455,872. It was placed in operation November, 1926.

Major construction projects as accomplished since the plant was placed in operation are as follows: (1) In 1932, separate sludge digestion units consisting of a Chain Belt primary tank, one digester equipped with floating cover, and a sludge-pump building were constructed. (2) Complete rehabilitation of the trickling filter beds was made necessary in 1941 due to disintegration of the filter media. The project entailed removal and screening of all the filter stone and reusing that portion which was retained on a 1½-in. screen. Twenty inches of new limestone and 14 in. of quartzite were utilized to refill the filters to the former 8-ft. depth. The cost of the above listed improvements totaled $117,874.

Operation of Pumping Stations

Triturator Repairs

Grit deposited and removed from the cage screens at Station 1 totaled 476 cu. ft. The grit was hauled weekly from the station to the treatment plant and disposed of by burying.

Unusual trouble was experienced in keeping the Triturators in repair during the year. On two occasions, once each at Stations 1 and 2, teeth were broken while the machines were in operation, causing damage to several of the 48 teeth in each set. Thus, 13 new teeth and resharpening of both sets were required. At Station 2 it was determined that a broken wedge bolt was the cause of the damage and a new set of wedge bolts and resharpened teeth were installed on June 15, 1945. At Station 1 the cause of damage was attributed to cracks in the teeth which developed in the process of resharpening. More rigid inspection of the teeth after resharpening has been assured by the manufacturer, who repaired the damaged set without charge.

Sewage Treatment Plant Operation

Sludge Digester

For the first time since the digester was placed in service in 1932, the tank was emptied for inspection of heating coils and for needed repairs.

The heating coils were found to be only slightly caked with a flint-hard, lime-like coating which was from ⅛- to 3/16-in. thick on the top half of the pipe and 1/16-in. thick on the bottom half. Scraping tools made by sharpening the long edge of old files were used in removing the scale. The thicker scale on the top portion of the pipe chipped and broke off most readily, although much scraping and wire brushing was required to remove the scale from the bottom half. No rusting or pitting of the pipe had occured and its appearance was like new after being cleaned. The time spent on cleaning of the pipe approximated 120 man-hours.

Repairs to the floating cover included the renewal of the shaft bolts on the bottom set of guide rollers and rewelding of all vertical seams on the apron below the cover plate. Old welds had deteriorated and broken out in places, leaving openings as wide as ½ inch. The welded joints were further reinforced by welding a ⅜-in. by 3-in. bar over each seam.

The 3-in. gas line between the control house and digestion tank was replaced. As had been suspected, because of the grass growth having died out over the line, a leak was definitely

detected in the gas line when city water pressure was connected for testing. In excavating, it was found that the pipe had pulled out of the elbow joint at a point near the digester wall. Flexibility had not been provided at this joint connection, and the weight of the dirt over the pipe caused the damage, the line being installed at a considerable depth at this point. The new line was relaid at a shallower depth, especially at the digester end, and by use of two 45° bends at each end was so installed as to allow for some give at the joint connections. The pipe was wrapped with a special no-oxide paper and given two coats of no-oxide paint, products manufactured by the Dearborn Chemical Company.

To prevent freezing of the exposed gas line on the digester cover, occasionally experienced in past years, a removable insulated wooden structure was built and installed on the tank wall to protect the piping at the flexible joint connection. The remaining pipe was wrapped with a padded, balsam-wool insulating paper and further covered with waterproofed no-oxide paper. This proved most effective in correcting freezing troubles and it is planned to adopt this procedure as routine preparation for winter operation.

TABLE I.—Summary of May 1945–May 1946 Operating Data of the Elgin (Ill.) Sanitary District Sewage Treatment Plant

Item	Average
Total rainfall (in.)	38.85
Estimated connected population	35,000
Sewage flow:	
Average daily (m.g.)	4.87
Average daily (gal. per capita per day)	139
Grit removed from raw sewage (cu. ft.)	925
Settleable solids (ml. per liter):	
Raw	1.6
Imhoff tank effluent	Tr.
Primary settling tank effluent	0.1
Filter effluent	0.3
Final effluent	0.2
Suspended solids:	
Raw (p.p.m.)	129
Imhoff tank effluent (p.p.m.)	65
Primary settling tank effluent (p.p.m.)	71
Filter effluent (p.p.m.)	46
Final effluent (p.p.m.)	38
Per cent removal	71
B.O.D.:	
Raw (p.p.m.)	136
Imhoff tank effluent (p.p.m.)	91
Primary settling tank effluent (p.p.m.)	99
Filter effluent (p.p.m.)	45
Final effluent (p.p.m.)	40
Per cent removal	70
Nitrate-nitrogen:	
Filter effluent	7.6
Final effluent	7.6
Filter loading:	
Pounds B.O.D. per acre per day	2,485
Pounds B.O.D. per acre ft. per day	311
Cu. ft. media per lb. B.O.D. per day	142
Digester:	
Temperature (°F.)	91
Raw sludge:	
Gal. received per day	4,385
pH	6.5
Total solids (%)	3.98
Volatile solids (%)	79.1
Digested sludge:	
pH	7.2
Total solids (%)	4.17
Volatile solids (%)	60.2
Imhoff tank sludge:	
pH	6.7
Total solids (%)	3.66
Volatile solids (%)	64.3
Sludge removed from drying beds:	
Total cu. yd.	868
Average moisture content (%)	50.5
Pumping station cost ($):	
Total operating cost	11,124.23
Operating cost per m.g. pumped	6.25
Sewage Treatment plant costs:	
Total cost ($)	40,386.21
Per m.g.	22.70
Per capita	1.15
Operating cost:	36,821.70
Per m.g. ($)	20.70
Per capita ($)	1.05
Wages (% of total)	56
Electric power (% of total)	29
Administration (% of total)	9
Operating supplies, etc. (% of total)	6

Laboratory

Laboratory tests consisted of analyses of 24-hour composited samples made up of portions collected at two-hour intervals. Composite samples were collected, in general, on Monday through Friday of each week, analysis being made on an average of 18 days each month, or a total of 217 days.

The data indicated that the effluent produced was comparable to previous years.

As reported last year, the azide modification of the Winkler method was adopted as routine procedure for dissolved oxygen determinations to overcome interference by nitrites. A change to phosphate buffered (Formula C) water in place of the bicarbonate water, as formerly used for dilutions in determining B.O.D., was made at the same time.

Table I is a summary of the operation data for the year.

Annual Report of the Buffalo Sewer Authority for the Year Ending June 30, 1946 *

By John W. Johnson, *Works Superintendent;* George F. Fynn, *Chief Chemist;* and Cecil F. Seitz, *Chief Engineer, Sewers Dept.*

Pumping

The first serious breakdown occurred to Number 3 main sewage pump. One day while this unit was in operation the discharge valve suddenly closed. Stoppage of flow, thereupon, exerted a tremendous back-pressure on the pump and piping. Immediate examination revealed that the pump had been twisted on its foundation and that the 5-ft. diameter butterfly valve casting was broken on the east side of its central axis. Fortunately, the pump itself sustained only minor damage. Cause of failure was attributed to the erosion of the pin which held the rod from the hydraulic ram above to the valve. It is impossible to explain why the valve closed as pressures on the top and bottom surfaces were presumed to be equal.

Primary Sewage Treatment

Handling and transporting tank skimmings continued to be difficult because of the quantity and consistency of the material removed. After a study of equipment which might be better adapted for this service, including inspection of installations at other plants, a centrifugal pump embodying a screw-type impeller was selected and ordered.

The storage wells for retention of skimmings were revised to reduce the capacity in order to require more frequent pumping to the digesters. The modification was effected in the hope of preventing stiffening of the grease particles stored in the deeper well.

Plunger type sludge pump ball valves of wartime rubber had a tendency to soften under action of the oil and grease contained in the sludge and skimmings. These were often forced up into the suction or discharge lines. Trials employing balls made of hard rubber (bowling duck-pin balls) were made. The endeavor to overcome clatter and the danger of breaks to the balls and the valve seats by the use of soft rubber casings proved ineffective, so the test was suspended.

Disinfection

After eight years of service one section of the chlorine solution line within the Administration Building developed a leak. It was found that the rubber

* For previous extracts see This Journal, **11**, 6 1083 (Nov., 1939); **13**, 3, 392 (May, 1941); **14**, 2, 455 (Mar., 1942); **16**, 6, 1239 (Nov., 1944); **18**, 2, 319 (Mar., 1946); **19**, 1, 95 (Jan., 1947).

lining of the 8 inch steel piping had opened up along the longitudinal vulcanized joint. The breach allowed the corrosive chlorine solution to attack the steel piping. The situation was immediately discovered and, fortunately, no ill effects were suffered by any of the plant staff. It was possible to have new short sections of steel pipe relined by a local concern and replacement was rapidly made.

Sludge Disposal

Efforts to prolong filter cloth life were continued. A guide plate made of sheet plastic for the sludge cake discharge was placed on trial on one of the filters. Because this was set at a lower discharge point and was not as rough on the cloth as the steel plate, it very definitely has added to the length of service of filter medium. Waterproofing cloth fibers did not have the desired effect so the practice was discontinued. On the strength of good results from experimenting with a plastic cloth, a small quantity was ordered but delivery had not been made at the year's end. Use of non-corrosive winding wire, change of wire spacing, gage, or cross-sectional diameter seemed to make little difference in increasing the life of available canton flannel.

Additional baffles were added to the conditioning tanks to more easily disperse the chemical additions. Posting of percentages of chemicals used by shifts brought about a marked improvement when all operators endeavored to meet the lower theoretical values.

Installation of one dust-exhausting system was finally made in and around No. 2 incinerator. This is composed of collecting hoods over the ash removal doors and the air preheater. From these points dust is taken in and carried by ducts to a fan which exhausts the particles through the roof. Labor shortage prevented the contractor from completing some changes to improve the removal of dust from this system, but it is worthy to note that this method has eliminated much of the dust and smoke which prevailed during most operating periods.

Safety

After seven months with a perfect safety record two members of the plant staff were seriously injured, both hospitalized with broken limbs. Reenactment of these incidents was staged for the benefit of the staff, the causes determined, and preventive measures demonstrated.

Miscellaneous

With a new power contract in force it was possible to issue definite operating instructions to correlate the starting and stopping of electrical equipment in the various departments. Adherence to these rules has resulted in complete avoidance of exceeding the maximum power demand and has also reduced the overall energy charge.

Laboratory Activities

An inquiry relative to the value of the sludge as fertilizer resulted in further study. Analyses showed a water soluble nitrogen content of 0.12 to 0.15 per cent, with 1.4 per cent total nitrogen on composites. Samples were forwarded to the interested parties for further investigation. A composite consisting of portions of two years' sludge cake samples showed the following analysis:

Item	Per cent
Volatile matter	52.3
Humus	45.3
Silica	16.0
Calcium carbonate	15.8
Phosphorus (P_2O_5)	2.2
Total nitrogen	1.5
Potash (K_2O)	0.25
Iron and aluminum	9.87

A study of the effect of the introduction of live steam into the raw sludge line was made to determine the increased temperature resulting from the

procedure. From an initial temperature of 64° to 65° F., an increase of eight to twelve degrees was noted by the time the sludge reached the control box at the digestion tanks.

Maps, Plans, and Records

The program of completely checking and correcting the 27 district key maps, which show the general location of all sewers in the City as well as their sizes and profile numbers, has been further advanced during the year. Four additional maps have been checked and corrected, which makes a total of 23 that have been so checked and corrected and three that have been redrawn since this work was commenced.

During the year, the printed books of contact drawings of the work designed and supervised by Greeley and Hansen have been compared with the original drawings on file and corrected to agree with the actual construction. Through the use of these books, the handling of original drawings will be unnecessary.

During the year 989 photo-copy machine reproductions of records and other matter were made. Since the acquisition of this machine in late 1944, a total of 1573 copy prints have been made.

Operations of Sewer Patrol

Regular inspections of siphons, intercepting and overflow chambers and manholes, and other purpose chambers have continued to be made by the Sewer Patrol, which consists of three men with an adequately equipped truck. There are 244 such points of regular inspection in addition to 16 gauging stations in trunk sewers. A total of 7773 inspections have been made by the Sewer Patrol during the past year. In these inspections, con-

TABLE II.—Summary of 1945–46 Operating Data, Buffalo, N. Y.

Item	Average
Estimated population served	600,000
Equivalent population	890,000
Sewage flow (m.g.d.)	144
Grit removed (cu. ft per m.g.)	2.5
Laboratory analyses:	
pH raw sewage	7.3
Suspended solids:	
Raw (p.p.m.)	204
Final (p.pm.)	124
Per cent reduction	39.4
B.O.D.:	
Raw (p.p.m.)	146
Final (p.p.m.)	109
Per cent reduction	25.3
Chlorine demand:	
Raw (p.p.m.)	4.6
Supernatant liquor (p.p.m.)	331
Overall total (p.p.m.)	4.89
Presumptive Coliform bacteria:	
Raw (1,000 per ml.)	80.6
Effluent (1,000 per ml.)	1.51
Raw sludge:	
1,000 gal. daily	116
Per cent dry solids	7.2
Per cent volatile solids	68.5
Digested sludge:	
1,000 gal. daily	73
Per cent dry solids	8.8
Per cent volatile matter	60.7
Supernatant liquor:	
1,000 gal. daily	119
Per cent dry solids	2.1
Per cent volatile matter	53.6
Digestion tank operation:	
Temperature (°F.)	93.9
Sludge gas:	
CO_2 (per cent)	32.0
CH_4 (per cent)	60.8
B.t.u. per cu. ft.	607
Cu. ft. per capita	0.81
Cu. ft. per lb. vol. matter added	8.3
Incineration:	
Tons wet sludge cake daily	77
Pounds wet cake load per furnace hour	5,592
Per cent ferric chloride (dry basis)	2.87
Cu. ft. gas used per lb. sludge burned	1.36
Costs ($ per m.g. treated):	
Pumping	1.44
Office and general	0.66
Laboratory	0.35
Sedimentation and chlorination	1.95
Sludge disposal	2.42
Maintenance and repairs	1.47
Miscellaneous	0.75
Total	9.04

nections to the intercepting system have been found completely stopped in 176 instances with sewage overflowing the weirs to the overflow outlet, and in 48 instances connections have been found partially stopped.

Table II is a summary of the 1945–1946 operating data.

City of Jackson (Mich.) Sewage Treatment Plant Annual Report for the Fiscal Year Ending July 1, 1947 *

By A. B. Cameron, *Superintendent*

The sewage treatment plant has been in operation and given complete treatment to the sewage flows for the entire fiscal year ending July 1, 1947.

The strength of the sewage was practically the same as last year when measured as parts per million of suspended solids. The B.O.D. was appreciably lower for the current year, being 155 p.p.m. in 1946 and 131 p.p.m. in 1947. It is very encouraging to note that when checking plant performance during April, May, and June, the months when the plant was operated at rated capacity, the final

* For previous extracts see This Journal, **17**, 4, 837 (July, 1945); **15**, 5, 995 (Sept., 1944).

TABLE III.—Summary of Operation Data for the Jackson (Mich.) Sewage Treatment Plant for the Year Ending July 1, 1946

Item	Average
Connected population	50,000
Sewage treated:	
M.g.	2,741
M.g.d.	7.61
G.p.c.p.d.	150
Rainfall, total (in.)	31.10
Sewage analyses:	
Suspended solids:	
Raw (p.p.m.)	225
Settled (p.p.m.)	145
Final (p.p.m.)	14
Per cent reduction	93.3
B.O.D.:	
Raw (p.p.m.)	135
Settled (p.p.pm.)	95
Final (p.p.m.)	5
Per cent reduction	96.3
Lb. per cap. per day in raw	0.16
Dissolved oxygen (p.p.m.):	
Raw	0.9
Settled	2.0
Final	6.6
Oxygen consumed (p.p.m.):	
Raw	49.1
Settled	37.1
Final	7.8
Organic nitrogen (p.p.m.):	
Raw	8.2
Settled	7.8
Final	2.7
Ammonia nitrogen (p.p.m.):	
Raw	12.2
Settled	13.3
Final	13.0
Nitrite-nitrate nitrogen (p.p.m.):	
Final	0.1
Aerators:	
Mixed liquor susp. sol. (p.p.m.)	2,556
Ave. sludge index	50
Ave. air used (cu. ft. per gal.)	0.6
Primary sludge:	
Per cent solids	5.3
Per cent volatile	61
Ave. lb. dry solids removed per m.g. sewage	6.22
Return sludge (per cent)	18
Gas production:	
Total (1,000 cu. ft.)	19,707
Gas per lb. vol. sol. digested (cu. ft.)	24.1
Cu. ft. per capita per day	1.05
Cost data ($):	
Cost of operation	64,693.70
Revenue Bonds (retirement and interest)	42,343.70
Collection (billings, etc.)	12,998.75
New equipment	857.77
Lift stations and sewer maintenance	19,081.62
Insurance	976.92
Total	140,952.46
Cost per m.g. (fixed charges included)	45.27
Cost per m.g. (less fixed charges)	28.74
Cost per capita per day	0.06

effluent was maintained at a very high quality.

There was one serious break in the water line supplying the coolers for the blowers. In the main building, arrangements have been made so that in event of future breaks in this line treated sewage can be supplied to the coolers, thus avoiding the possibilities of a shut down. The aeration plates have deteriorated badly in the past year and so have started the process of cleaning and replacing bad plates with some extras we had on hand.

Sludge bed cleaning is still being handled by the Southern Michigan Prison with the following changes in the setup. The new Warden was not completely satisfied with the supervision given the prisoners, so he has detailed a guard to the sludge bed cleaning crew. Also, instead of depending upon inmate drivers for the trucks, the plant now supplies the driver. This will add slightly to our costs, but is definitely worth while from a plant viewpoint, as we will still get all labor for sludge bed cleaning gratis. On the whole, the sludge bed cleaning has not been overly satisfactory during the past year as we have been short much of the time on inmate labor. This has been due primarily to the numerous investigations that have been conducted at the prison and to the use of available labor on the prison farms during planting and harvesting times. Table III presents a summary of operation data for the year.

SAFETY MEASURES IN SEWAGE TREATMENT PLANTS *

By H. S. Smith

Stanley Engineering Company, Muscatine, Iowa

The importance of this subject is attested by its popularity as a sewage conference program topic. Safety might be considered boresome were it not for the continued appearance in the technical journals and newspapers of accounts of accidents at sewage treatment plants. When it is realized that for each published incident there are perhaps hundreds of unrecorded minor incidents it is well to discuss safety frequently. If an annual reminder of the hazards existing in sewage treatment plants will eliminate even one minor accident, then the time used to discuss safety will have been well spent. After all, the difference between a "close shave" and a really serious accident is purely a matter of chance, and it is up to the operators and designers of sewage treatment works to deprive fate of the opportunity to exercise her fickle whims.

Basis of Safety

Safety in sewage treatment as in any other field is largely a matter of common sense and the practice of the old axiom, "an ounce of prevention is worth a pound of cure." Adequate safety measures in a sewage treatment plant demand cognizance of the source of hazards, a healthy respect for these hazards, and an honest effort to eliminate or control them to the greatest possible extent.

Responsibility for Accident Prevention

Accident prevention in sewage treatment plants is the responsibility of both designer and operator. The designer must appreciate the various hazards and design to eliminate or

* Presented at the Annual Meeting of the Iowa Sewage Works Association; Cedar Rapids, Iowa; Oct. 9–11, 1947.

control them to the greatest possible extent. On the other hand, the operator must appreciate the fact that hazards cannot be eliminated entirely and that he must be constantly on the alert to control them. The operator's problem is all the more difficult in the older plants in which the nature of the hazards had not been fully appreciated by the designer and where extra precaution must be observed to avoid serious accidents.

This paper will discuss the following more important types of hazards in sewage treatment plants and the elimination or control of these hazards in both design and operation:

1. Gas hazards arising from the production and utilization of sewage sludge gas.
2. Physical hazards arising from the possibilities of falls, drowning, electrocution, etc.
3. Health hazards arising from the many sources of infection and disease.

Importance of Design Features

Much can be accomplished toward elimination of hazards by designing with careful attention to sources of hazards and arrangement of details so that these hazards are eliminated or easily controlled. A well-designed plant from a safety standpoint need cost but little more than a plant designed with only secondary regard to safety, and the resultant added cost, if any, of such safety details will be well repaid in accident prevention. It is also well to note that a plant designed with due regard to safety is also more convenient to operate, and higher operating efficiences may be expected from such plants.

It is not safe to rely entirely on trained operators to assist in control of hazards since, unfortunately, operating personnel is generally beyond control of the designer. The designer must, therefore, make his safety precautions as simple and straight forward as possible.

Gas Hazards

Gas hazards constitute the most obvious and spectacular source of accidents at sewage works. Sewage gas hazards include not only explosion hazards but also hazards due to the toxic and suffocating properties of gas.

Since gas production and utilization is an essential phase of modern sewage treatment, it is obvious that it cannot be eliminated but rather must be controlled.

Explosions

Any gas explosion is the result of four factors: (1) the presence of an inflammable gas, (2) the presence of oxygen, (3) a proper mixture of the two, and (4) a source of ignition. No explosion can occur in the absence of any one of these factors. Gas and atmospheric oxygen are always present at sewage treatment plants and sources of ignition are so unpredictable that it is impractical to consider them controllable within the limits of absolute safety. It is possible, however, to control the formation of explosive mixtures of gas and air by the relatively simple expedient of keeping them separated.

Toxicity

Hydrogen sulfide is the common toxic constituent in sewage gas. This gas has about the same lethal power as hydrogen cyanide. Concentrations of from 0.06 to 0.10 per cent are fatal in 30 minutes or less, and concentrations in excess of 0.20 per cent cause almost immediate cessation of breathing due to total paralysis of the respiratory system. Although the repulsive odor of this gas is very noticeable in lower concentrations, it is well to note that the odor is not so pronounced in near-lethal concentrations due to its paralyzing effect. This property may give rise to a false sense of security.

Suffocation

Although the other constituents of sewage gas such as carbon dioxide and methane do not have the deadly effect of hydrogen sulfide, they may decrease the oxygen content of the air and cause asphyxiation if allowed to accumulate. It should be noted that some gas constituents are heavier than air and will tend to accumulate in pits and other low-level, unventilated areas, making them especially hazardous.

Control of Gas Explosion Hazards

In order to control gas hazards it is essential that the design provide for: (1) complete separation of air and gas to eliminate formation of explosive mixtures, (2) adequate positive ventilation of all areas where gas might escape or accumulate, and (3) elimination of pits or chambers which are not susceptible to adequate ventilation.

Gas Collection

The simplest method of assuring separation of gas and air in a digestion tank is to keep the gas within the tank under pressure at all times. This condition is normally assured by a floating cover but can be achieved in a fixed cover tank only by providing for the replacement of liquid whenever sludge or liquor is withdrawn, which will keep the tank liquid level above the point necessary to maintain positive gas pressure.

Safe Gas-Piping Systems

The gas-piping system should be a closed system, with all parts of the system as strong as the pipe itself. This requirement will prohibit water seal devices of all types since such seals may blow out or evaporate, thereby permitting gas leakage.

The gas-piping system must be carefully arranged to provide ample slope to drip traps at low points for removal of condensed moisture. Float-type drip traps are not desirable since it is possible for the needle valve to be held open by sediment, thereby permitting condensate water to drain completely away and gas to escape into the room. Manual drip traps in which the gas inlet to the trap is automatically closed when the drain is opened will eliminate any hazardous possibility. Of course, such traps must be accessibly located if effective servicing is to be expected.

Manometer gauges are commonly employed to show gas pressures at critical points in the system. The tubes of these gauges may be broken and it is, therefore, desirable to arrange for them to vent to the outside atmosphere.

The proper application of well-designed protective devices such as flame traps and pressure-vacuum reliefs is essential to the safety of a gas system.

Flame Traps

An effective flame trap must provide flame protection against sustained burning within the unit and protection against explosive flash backs. A wire gauze screen alone will not provide this protection since sustained burning on the surface of the gauze will quickly cause the gauze to become hot enough to reignite the gas on the protected side of the unit. It is questionable if any pipe-line flame trap element can be designed to withstand internal burning on the surface of the element, and it is, therefore, necessary that the flame trap include an automatic gas supply shutoff. This is usually accomplished by a thermal shutoff, with the thermal element located in the burning zone.

Flame traps must be provided for all units burning with an open flame. They should be located as close as practical to the source of the flame, since explosion pressure-intensity increases with the length of pipe between the source of flame and the trap. Flame traps may be subjected to explosive pressures and should, there-

fore, be designed as strong as the piping system, which will normally withstand pressures up to 125 to 150 lb. per sq. inch.

Pressure and Vacuum Relief

The normal gas system requires some means of automatically wasting gas when the rate of production is in excess of the rate of use. Excess pressure relief for digesters in case of line stoppage is also necessary. Diaphragm-actuated relief devices, with adjustable pressure weights, will provide the close control required. However, these units should be provided with a vent to outside atmosphere to prevent escape of gas into a building in the event of diaphragm rupture. These units are often combined with flame traps to provide protection against flame entrance from a waste gas burner or from an outside source of ignition in such applications as a digester relief.

Digester pressure relief units are also designed as vacuum relief units to prevent structural failure of the tank in the event of low liquid level in the tank. This is an operating condition to be avoided, but, should it occur, it is most essential that the relief device include a flame trap to prevent ignition of the gas-air mixture in the tank. Such traps are commonly designed with sufficient exposed area to dissipate the heat from the element, thereby making a shutoff device unnecessary.

Boiler Gas Controls

Particular attention should be given to boiler gas controls. Each boiler should be equipped with approved thermo-pilot devices which will control a snap action gas supply shutoff so that the supply will be shut off if the pilot light fails for any reason. A high-temperature shutoff should also be incorporated in the boiler controls.

Electrical Equipment

Motors, switches, or other electrical devices should not be located in a zone subject to possible explosive gas-air mixtures if such location can be avoided. Complete removal of electrical equipment from these zones is not usually possible. Such devices as must be located in these zones should be of an explosion-proof type designated as suitable for "Class I, Group D, Hazardous Locations" by the National Board of Fire Underwriters.

The safety of any gas system may be greatly enhanced by the provision of an isolated gas control room or chamber in which flame traps, meters, boilers, and other appurtenances are located. Such a room should be accessible only from an external ground level entrance. If the space is provided as part of another plant structure, there should be no means of communication between the room and the other structure, and all conduit, piping, or other services entering the space should be securely sealed to the structure to prevent gas escaping to other parts of the building.

Control of Toxicity and Suffocation Hazards

The proper application of the measures previously discussed will provide the sewage works with the safety devices normally necessary for control of the gas. It is still necessary, however, that the designer provide for protection of the operator against emergencies or against the slow accumulations of gas that are found to occur in any system. Gas control chambers require especially careful attention but the problem is not confined to these areas since the possibilities of slow gas accumulation are present in almost all confined spaces of the ordinary plant.

Plant arrangement should be such that ground level entrance is provided to all chambers. Those areas that are

below ground should be arranged so that they need not be entered in normal operating routine. Valve stems may be extended to the ground floor to eliminate the need of entering these areas for valve operation. Access to such areas should be by stairs rather than ladders since a man in difficulty may crawl up a stair but might not be able to make the effort necessary to climb a ladder.

Adequate Ventilation

Adequate forced-draft ventilation of all spaces where gas may accumulate is an essential part of modern plant design. Natural-draft ventilation is unsatisfactory due to limited capacity and the fact that certain constituents of sewage gas are heavier than air and cannot be removed from the lower portions of chambers except by forced draft. The forced-draft ventilating system should have sufficient capacity to change the air in the ventilated space in from 2 to 3 minutes and should be provided with inlets at both floor and ceiling levels. The fan switch should be located at the entrance to the chamber and preferably arranged so that either opening the door or turning on the lights will also start the fan.

Physical Hazards

The ordinary sewage treatment plant with its open tanks, many floor levels, electrical equipment, and other hazards of this type is inherently a dangerous spot. Many of these hazards can be minimized or eliminated by careful attention to design details.

Generous use of handrailings around open tanks and wells and on stairs and platforms is an obvious safety measure. Such railings should be of substantial construction.

Slippery Surfaces

Particular attention should be given to walk and floor surfaces in exterior and interior locations subject to moisture to avoid wet, slippery surfaces which may cause falls. Non-slip surfaces may be achieved by float finishes or by special abrasive concrete admixtures where smooth, easily cleaned surfaces are desired.

All outside walks and stairs should be sloped to drain so that water will not pond on them. Proper drainage will materially assist in the elimination of treacherous icy surfaces in cold weather.

Ladders and Stairs

Careful attention should be given to means of access to different levels. Ladders should not be used as a means of access to possible gas hazard zones, as discussed above, and should be avoided at all other points wherever practical. A ship ladder or circular stair is preferable to a conventional ladder and may be used when space is at a premium. An "easy" stair should be used for access to all points required to be reached in routine operation. An "easy" stair is one in which the ratio of rise to run is such that it can be used with normal step. The old carpenter's rule that the sum of two risers and one tread should be between 24 in. and 25 in., and the product of a riser and tread should be between 70 and 75 is a good guide to an "easy" stair layout. Long runs of stairs should be broken by platforms at about 10-ft. height intervals. When necessary to use a ladder, the ladder should be extended above the upper floor level to permit easy access to and from the ladder.

Electrical Equipment

The need for explosionproof electrical devices has been discussed as a part of gas hazard control. The other portions of the electrical system also require careful attention to eliminate the usual hazards. National Electrical Code requirements should be observed in the layout of the electrical system. This code, if followed, will provide a

guide to safe arrangement of controls and wiring. Particular attention should be paid to the use of suitable materials. Moistureproof or weatherproof controls and motors should be used when required. Insulation should be a type suitable for the particular conditions of installation, to avoid deterioration. An adequate grounding system is essential as a safeguard against severe shock in event of system fault. The location of various electrical controls deserves considerable thought. They must be easily accessible and arranged for operation in a dry location.

Adequate lighting will prevent accidents and is an important safety measure. Consideration should be given to both natural and artificial lighting requirements.

Fencing

A climbproof fence around the plant is a desirable safety measure for protection from would-be trespassers. It will prevent entrance of unauthorized persons who might be unnecessarily exposed to plant hazards.

The control of physical hazards in design is essentially a matter of the application of well-established safety principles to the particular hazards existing in sewage treatment plants.

Health Hazards

Some direct contact with sewage or its byproducts is inevitable, but attention to details, such as the arrangement of channels and screen chambers for convenient cleaning, may partially eliminate the need for or reduce the degree of contact, and thus reduce the chance of infection.

An example of an apparently innocent detail which led to the necessity of unusually frequent cleaning of sludge pump valves was demonstrated forcibly to the writer in one of his first contacts with a sewage treatment plant. The plant was new, with crushed rock walks in place of concrete. It was inevitable that rock particles would be kicked into or fall into the primary settling tank and, as a result, the writer received a first hand lesson in the pleasures of removing obstructions from sludge pump ball valve seats. There is no way of knowing how many times that pump has had to be cleaned because of the stone chips. Each time has been a definite health hazard to the operator.

Cross-Connections

The many opportunities for cross-connections between a safe water supply and sources of pollution in sewage treatment plants require the careful attention of the operator. These opportunities include such possibilities as makeup connections to heating systems and to pump water seals. Needless to say, such cross-connections should be entirely eliminated.

Physical Contact

Since some contact with sewage may be expected it is important that facilities for personal cleanliness be provided at each plant. Such facilities require a source of safe water, which may be provided by a small well and pressure system if the plant is far removed from the municipal water system. Sanitary facilities may vary with the number of personnel employed but as a minimum should include a toilet and lavatory, with medicine chest for storage of first aid items.

From a health standpoint, sewage plant safety consists of minimizing the opportunities for contact with sources of infection and providing sanitary facilities for thorough cleansing when such contact is necessary.

Safe Operation Practices

Even with modern design practices it is impossible to make a plant foolproof, and it is essential that the operator know and respect the many hazards that will exist in even a well-designed plant. It is even more im-

portant that he be aware of the multitude of hazards that beset him in older plants which do not have modern safety measures. Knowing the sources of these hazards and their nature, he must adopt his own operating safety measures. The operator must know how the safety measures which were incorporated in the plant design are intended to function and he must see to it that such measures are maintained in top operating condition.

No attempt will be made to give a set of rules for safe operation. Methods of safe operation vary in each plant. A brief discussion of accepted operating practices for control of various typical hazards, however, may serve to make operators aware that the job of safety is only begun in design.

Gas Hazards—Explosions

A thorough understanding of the gas system and the function of each safety device on the system is essential to proper and safe operation. A large scale diagram of the entire gas system showing each device, with pertinent notes explaining the function and required servicing of each device, will aid in acquainting the operator with the problems of his plant. Such a diagram may be posted in a conspicuous place as a reminder of the proper functioning of each unit for safe operation.

A definite schedule of gas equipment inspection should be adopted to insure proper operation of all protective devices. Flame trap elements should be inspected to check for clogging or corrosion and to check operation of the shutoff valve. Boiler controls must be carefully checked to assure proper functioning of protective devices. These inspections should supplement daily observations of gas pressure at critical points in the system. Any departure from normal pressure should be immediately investigated and the cause removed.

Careful attention must be given to keeping the gas system free from condensed moisture. Normally, this may be accomplished through the drip traps, but gas meters and other units should also be frequently checked for moisture which may interfere with their proper functioning.

Operation of fixed cover digesters requires careful attention when withdrawing sludge or liquor. Such withdrawals should be accompanied by simultaneous additions of liquid to maintain liquid level, thus preventing the formation of an explosive gas-air mixture.

Even with the gas collection system maintained in top condition there is still the possibility of trouble due to inadvertent gas accumulations or slow leakage. It is essential, therefore, that all possible sources of ignition be eliminated. Electrical equipment in zones subject to gas accumulations should be of the explosionproof type and must be maintained in an explosionproof condition. No open flame of any type should be permitted in the vicinity of tanks storing or producing gas. These areas should be conspicuously posted with "No Smoking" or "Danger—Gas" signs.

Gas Hazards—Suffocation

So far only the control of explosive hazards of gas has been discussed. Consider for a moment the more subtle, but none the less deadly, hazards of poisoning and suffocation. Occasionally it is necessary to enter a zone where gas may have displaced air, or where high concentrations of hydrogen sulfide may exist. In case of doubt it is only safe to assume that such conditions do exist and to act accordingly. Such areas should be ventilated as well as possible and should never be entered unless another person is on the outside with access to a gas mask or other rescue means. A rope around the person entering the area may be all right, but be sure there is sufficient power available outside to remove the person if he is overcome.

If a plant contains deep chambers or pits which must be occasionally entered, a portable blower for ventilation of these areas will be a valuable piece of equipment.

A word of caution on gas masks. Remember a cannister mask is worthless in an oxygen deficient atmosphere. The cannister will only remove impurities, it will not supply oxygen when none is present. A hose or oxygen mask is the only effective equipment in such cases.

Physical Hazards

Good housekeeping is an operating policy as important to accident prevention as it is to general operation. "A place for everything and everything in its place" will eliminate the possibility of stumbling over miscellaneous objects dropped around the plant. Keeping walks, stairs, and floors free of moisture or sludge accumulations will eliminate slick spots. This is particularly important in winter when failure to remove outside water or ice from walks will result in exceedingly treacherous conditions.

Maintenance is a special phase of good housekeeping but is absolutely necessary if the safety measures incorporated in the plant are to remain effective. Railings, walks, stairs, ladders, etc., must be maintained in structurally sound condition. Corrosion conditions are particularly severe in treatment plants and the rate of deterioration of an essential protective device may be surprisingly fast.

Maintenance and safe operation of electrical systems deserve special consideration. Great care must be used to watch for deterioration of insulation and protective devices which may result in dangerous system shorts. Stories of accidental death resulting from operating electrical appliances while standing in bathtubs may demonstrate the acme of carelessness, yet how many times sewage works men have operated switches while standing on a wet floor. This hazard, if it exists, can be eliminated by simple wood platforms or rubber mats. Don't be as foolish as a power plant operator of the writer's acquaintance who boasted of testing his 2,300 volt line by flicking the blades of a disconnect switch. That man's assistant, incidentally, was electrocuted while working under his instructions.

Scaffoldings and temporary ladders deserve special mention. These items are often necessary for special maintenance and repair. Don't take a chance. Make sure that they are structurally sufficient, and erected so as to prevent slipping. Use them with caution, realizing that they are of temporary construction.

Health Hazards

A general rule for control of health hazards might well be "Keep it Clean." No operator should be censured for having clean hands. Copious use of soap and water is an excellent germicidal treatment.

The use of rubber gloves may not avoid operator's dishwater hands, but it will minimize the hazard of exposure to infectious material when hand contact with sewage or sludge is necessary.

A first aid kit with fresh ingredients is a must for safe operation. It is not enough that the kit be available, it must be used. The old axiom that "serious infections from little scratches grow" is absolutely true at sewage treatment plants.

General Safety Rules

Each plant, large or small, should develop its own set of safety regulations to fit its own particular circumstances. Such regulations need not be elaborate. Even a simple set of rules, conspicuously posted, will achieve the first principle of safe operation, namely, "safety mindedness." If this condition can be achieved, the major

battle in safe operation will have been won.

Summary

The foregoing discussion may serve as a basis for the development of a set of operating safety regulations but is by no means all inclusive. Such things as operator training in artificial respiration and first aid should be a definite part of any safety program. The goal of this discussion has been to refresh memories concerning the hazards which beset the sewage plant operator and the duties of designers and operators in minimizing these hazards.

TIPS AND QUIPS

Gone, But Not Forgotten

As it must to all, the high cost of living finally caught up with *The Corner*. Pinched between pyramiding JOURNAL printing costs and the necessity for observing budget limitations, something had to give. Thus it became necessary to reduce by a considerable number of pages the space allocations for the remaining 1948 issues of the JOURNAL.

In accepting its share of space reduction, *The Corner* has been forced to forego, for a few issues at least, one of its long-time features—the "Bark From the Daily Log." That this was done with great reluctance will be obvious to the many JOURNAL readers who have followed The Log through the years.

Originally the creation of Editor Wisely, The Log has had a distinguished list of contributors since its inception in 1941. The last of these have been W. W. Mathews and Walter Sperry, who have prepared The Log for alternate issues of the JOURNAL since 1947.

Designed to bring to JOURNAL readers the day-to-day human interest experiences of sewage works operators, The Log has admirably filled this niche in *The Corner*. Many a chuckle and laugh has been passed along by it, as well as a few sighs and moans! And the number of operation and maintenance helps that have become common property through its pages is legion.

To all of the Loggers who have shared with JOURNAL readers a bit of their experience, philosophy, and wit, and particularly to W. W. Mathews and Walter Sperry, *The Corner* reluctantly says *au revoir*—but not goodbye!

The Voice of Experience

In a recent letter, F. G. Diefendorf, superintendent of sewage treatment at Erie, Pa., voiced a complaint on current sewage treatment works design that will be echoed fervently by many a brother operator.

Diefendorf's comments are as follows:

"From my experience I believe that about the biggest mistake in building a sewage treatment plant with sludge drying beds is the omission of adequate means for cleaning and removing the sludge from the beds.

"Such equipment could almost invariably be included in the original contract for the plant. It is almost impossible to obtain money for such equipment after construction when the equipment is needed.

"Our experience here in the last few years is that by contract it is almost impossible to get the beds cleaned when they should be cleaned and the contractors ruined the beds with the equipment they used."

The complaint voiced in the above comments could be made with justice by nearly all sewage works men. Save for the larger metropolitan plants, consulting engineers have failed badly in

this phase of sewage works planning. They have followed, apparently oblivious to the facts, the fallacy that equipment for cleaning sludge beds should or would be provided after a plant is placed in operation, or have ignored the problem completely. This is also true of other items of maintenance equipment.

Sewage works men can assist materially in assuring the inclusion of satisfactory sludge bed cleaning and other desirable maintenance equipment in future sewage treatment projects by presenting their experiences and suggestions frankly and sincerely to consulting and design engineers.

Mobilization in Michigan

The Twenty-First Annual Meeting at Detroit next October 18th may seem a long while away for some Federation members, but not for those located in Michigan. They all have been registered, indoctrinated, organized, and alerted. They await only the arrival of October. A recent communiqué to all Michigan sewage works men, as released through the *Michigan Sewage Works Bulletin*, warns: "Absence of your name from the (committee) list should not be assumed as authority for any presumption that you, as a member of the Michigan Sewage Works Association, have no further responsibility beyond transporting yourself to convention headquarters.

"You may reasonably assume that you may at any time receive one of those messages—beginning 'Greetings,' and then telling you when and where to report."

As a sort of second indorsement, the above communiqué continues: "An inspection trip is planned to the Detroit and Dearborn plants, but perhaps some of the rest of you operators had better plan on a few visitors too. This Federation group is a most *uncontrollable* * crowd and it would not be at all surprising if they wander anywhere within a hundred mile radius of Detroit."

Well! Never let it be said there won't be plenty of room to enjoy yourself at Detroit. That should be area enough for even the Texans, although they'll probably never admit it. Keep your eye on these pages for the date on which the women and children will be evacuated from the area to be occupied by you "uncontrollable" Federation members!

Paint Protection

If one picture is worth a thousand words, no further explanation is needed for the above photograph of signs painted with the new phosphorescent or luminous paint. Even fewer words will be needed to suggest to smart operators innumerable ways a good luminous paint can be used as a safety aid at sewage plants.

Ending Window Problems

Everyone appreciates a room with a view, but when the view is obtained only at the cost of vexing maintenance and replacement problems, critical appraisal of the view and its value is in order. The maintenance of window sash and frames has always been a primary problem at sewage treatment works, with operators rarely able to hold their own in the continual battle against moisture and corrosive gases

* *Editor's italics.*

such as hydrogen sulfide. Eventually decay and corrosion always win and expensive replacement of either frames or sash, or both, becomes necessary.

An increasing number of operators are insuring against increasing future maintenance costs by replacing decayed and corroded window sash and frames with glass brick. Trading of a view for freedom from moisture, corrosion, insulation, and maintenance problems seems like a good bargain to many sewage works men. Glareless light and virtual freedom from the chore of window washing are bonus values glass brick provides.

The balancing of the cost of closing selected window areas with glass brick against the present cost of maintaining such window areas might be a worthwhile and surprisingly profitable study, even though window replacement is not an immediate problem.

Low-Cost Oxygen and Sewage Treatment

An unpublicized industrial revolution may be just ahead whose impact on sewage treatment could be as terrific as it will be on the oil and coal industries.

It seems certain that $2 per ton oxygen is only a matter of months away. Of little significance to the average man now, when low-cost oxygen becomes a reality the way will be opened for the synthesis of all types of petroleum products from natural gas and oxygen, and the conversion of coal of all grades into high-methane gas and petroleum fractions.

Construction of oxygen plants in the huge natural gas fields of the Southwest will add to the country's dwindling natural oil reserves the unknown billions of cubic feet of untapped natural gas. Low-cost oxygen produced at coal mines, wherever their location, will provide unlimited supplies of gas and fuel oil only a relative stone's throw from the great centers of industrial production.

Plants are already being built which will produce oxygen for less than $2 per ton. One such plant in Oklahoma will have a greater capacity than the country-wide production of oxygen in 1945, peak year of wartime production.

Although feature writers have not as yet dramatized in national publications the probable effects of low-cost oxygen on accepted sewage treatment practices, a few moments contemplation will impress anyone with the possibilities of the future. While many of these "day dreams" will not meet the rigid requirements of practicability, the prospect of accelerating biochemical reactions by the use of oxygen-enriched atmospheres, the pretreatment of certain industrial wastes by direct chemical oxidation, the possible use of portable low-cost oxygen-producing equipment for maintaining desirable oxygen balances in seasonally polluted streams, all furnish ample food for serious thought.

Research on the more rapid utilization of oxygen in biochemical oxidation processes is already underway at two universities, and one nationally known stream pollution control agency is closely following developments in the low-cost oxygen field, both in this country and abroad. Portable equipment may be available shortly capable of producing quantities of oxygen consistent with stream requirements, and at reasonable cost.

That low-cost oxygen will be an accomplished fact is certain. The evolution which its advent will produce in sewage works operation, of course, is debatable. Perhaps oxygenation will become as common as chlorination is now.

First for Forty-Seven

D. E. Henn, superintendent of the De Kalb (Ill.) Sanitary District, was the

author of the first 1947 annual operation report to reach Federation headquarters. An early bird in this regard, Henn's report arrived March 1st and was up to its usual high standard.

Happily, the De Kalb report was not the last one received, as each week several more arrive. These annual reports represent real contributions to the literature of sewage works operation.

The Corner will continue to carry interesting extracts from as many annual reports as space will permit. As far as can be determined, the "Interesting Extracts" section of *The Corner* is the only place reliable plant operation data is regularly reported.

Avoid Distress at Detroit

The acme of human despair, futility, and sometimes rage can be observed at the room clerk's desk of any hotel during any convention. The proverbial hardness of granite is as nothing in comparison with the calloused indifference of a room clerk's heart—when the house is full. Undoubtedly the high-pressure American heart has suffered more damage at the desks of these "servants" of the traveling public than it has at the refreshment counters of the adjacent tap rooms and bars.

Of course, usually the hotels' guests (?) have only themselves to blame for their indulgence in the great American practice of doing tomorrow what should be done today. The point is this, however, no one wants to see the despairing faces of FSWA members congested around room clerk desks at Detroit next October 18th! Accordingly, here is a respectful suggestion that all who have not already done so take pen in hand and get that room reservation in NOW!

Hotel Statler will be the convention headquarters. The block of rooms reserved there for Federation members is large but will not accommodate all who wish to be located at the convention hotel. To avoid disappointment make your reservations as quickly as possible, directly with the hotel management. The Book-Cadillac Hotel, a few blocks down the street, is another fine place to stay and also has set aside rooms for those attending the 21st Annual Meeting.

There are other good hotels in Detroit also, but the evening of October 17th will be a poor time to hunt them!

Editorials

A MORALE PROBLEM

There have been a number of indications recently that the morale of operation personnel in small sewage treatment plants is generally at a low level. This is not a local condition, restricted to any one region, nor has it been abrupt in its onset. There is a real need for recognition of the situation, attested by the present poor condition and inadequate performance of many small plants.

There was considerable relaxation during the war of maintenance and operation standards because of the need to conserve manpower and critical materials wherever possible. Turnover in personnel was heavy on account of military enlistments and opportunities in industry. Depleted technical staffs of state departments of health and other pollution control agencies made it necessary for them to curtail field inspections and associated operation supervision activities. The small-plant operator gradually became the "forgotten man," left to get along as best he could, with almost no evidence of concern on the part of others in what he was doing.

Continuation in the postwar period of some of the above conditions, plus the overwhelming activity in planning and construction of new and expanded treatment facilities, has prevented correction of the situation. If anything, greater than ordinary emphasis on plant operation is justified at this time because of the general prevelence of overloads.

The mental attitude of an operator toward his work is highly important. Even the most conscientious individual may become slipshod in his methods if he loses enthusiasm and interest in his occupation. And he is likely to lose initiative if there is continued lack of outside appreciation of his efforts.

There is a close relationship between the performance of small municipal sewage works and the intimacy of contact with the state office that is responsible for operation supervision. Aside from the technical assistance and instruction that is given by the state field engineers, the operator is given a mental "lift" by such visits. He has learned that these engineers are friendly advisors—not inspectors—who appreciate good work and are quick to commend it.

Further, the inspection reports that are sent to the municipal officials following the engineer's visit serve a manifold purpose. They remind the council that the town does have a sewage treatment plant and that Joe Doaks is operating it with good or indifferent success. They contain forceful recommendations with regard to facilities and procedures that are much more likely to be followed than if requested only by the operator. Local awareness of the sewage works is maintained, making the operator more conscious of the results of his labor.

The same advantages result from the routine review and acknowledgment of monthly operation reports. A few state pollution control agencies further enhance their operator contacts by means of periodical newsletters, such as the Indiana *Sewage Gas*, the South Dakota *Clarifier*, the Illinois *Digester*, and others. Such publications are most effective in maintaining morale.

Most of the state sanitary engineering bureaus engaged in sewage treatment supervision are now back to full staff strength, and ready to resume their pre-war programs. Many of these agencies are planning to expand and intensify their activities. They will all do well to give immediate attention to the operation of sewage works, particularly those in smaller communities.

The Member Associations of the Federation can also contribute to the existing need, and many of them have been doing excellent work in collaboration with state agencies and educational institutions. Sectional operators' conferences, short courses, and certification programs are usually conducted under such joint sponsorship, and they are highly productive in the encouragement of better plant operation.

Individual participation in these functions, however, is purely voluntary. There is not at present nearly the degree of interest in them that there should be, which is a sound

indication of the need for promotional activity.

The best morale builder, of course, is a salary check that is commensurate with the caliber of plant supervision that is required. Here again, it is the state bureau holding responsibility for sewage works operation that must do much of the selling job in specific cases. Consulting engineers can also help in educating municipal officials on the necessity for salary budgets that will attract and hold competent operators.

Whether it is caused by lack of treatment facilities or lack of proper operation of an adequate sewage treatment plant, it is still stream pollution. For which cause is there least justification?

W. H. W.

MUNICIPAL BUYING PRACTICES NEED STREAMLINING

The chlorine supply situation has concerned a number of sewage and water works officials in recent years. A frank and enlightening discussion of this topic in the Manufacturers' Forum held as part of the New Jersey Sewage Works Association meeting in March indicates that procurement by municipal purchases may not be eased for some time.

Defense plant needs and a shortage of containers were the first causes of tightened deliveries of chlorine to water and sewage works. Since the end of the war, however, producers of chlorine are confronted with a greatly changed distribution pattern that may influence deliveries permanently.

Pre-war consumption of chlorine in water and sewage works was about 12 per cent of total production; today it is but 3.5 per cent. This relegation of the municipal market to a minor one from the standpoint of volume has resulted from an enormous increase in chlorine consumption by industry, notably in plastics manufacture.

Most if not all chlorine producers feel a sense of responsibility in meeting the demand for chlorine used in public health functions, and they will certainly continue to meet these needs. There are two factors, however, which make the industrial chlorine market more attractive to the producer than is the municipal market: (1) the seasonal variation in demand for chlorine in water and sewage works, which does not favor installation of new production capacity; and (2) the complications and added costs of sales to municipalities. There is not much to be done about the first item, except to spread orders as much as possible without tying up containers. The second factor, however, is correctible.

Sales to industrial buyers are usually consummated quickly and directly, often simply by a telephone call to the purchasing agent. But municipal orders commonly require that two or more officials be contacted and sold, and sometimes that a council meeting be attended. There may be further complication when orders are required to be handled through a local dealer. Bidding may be required, often in compliance with state laws, and this adds to sales effort and costs.

If municipalities must compete with industry for materials that are in heavy demand it will be to their advantage to overhaul their purchasing procedures. All possible simplification of purchasing will add to the attractiveness of their market, and will expedite deliveries.

W. H. W.

Proceedings of Member Associations

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

13th Annual Meeting

Watertown, South Dakota, September 18–19, 1947

The Thirteenth Annual Meeting of the South Dakota Water and Sewage Works Conference, held at Watertown, September 18–19, 1947, was one of the best meetings held during the relatively short life of this organization. Seventy-nine members attended and a large number of guests were also present.

The opening session featured papers on fluorine and meter maintenance. A motion picture of the Bikini atomic bomb experiments was the highlight of the session.

The afternoon session of the sewerage group consisted principally of a general roundtable discussion on operation problems. Considerable interest was shown in the subject of plant records and laboratory tests, particularly as these apply to the small plant. The roundtable was under the leadership of Roy G. Spieker and J. L. Sorbel, of the South Dakota State Board of Health.

The annual banquet provided an interesting evening of entertainment and was under the direction of Toastmaster W. F. Cochrane.

The following papers were presented at the Feb. 19th, morning session:

"The Zeolite Process for Softening South Dakota Waters," by E. R. Mathews, sanitary chemist, State Board of Health, Pierre, S. D.

"Garbage and Refuse Disposal in North Dakota," by J. H. Svore, director, Division of Sanitary Engineering, North Dakota Department of Health, Bismarck, N. D.

"Pump Maintenance," by Joseph H. Hill, Fairbanks, Morse & Co., Minneapolis, Minn.

"Sewer Maintenance Problems and Equipment," by Ralph Reed, assistant city engineer, Watertown, S. D.

The 1947–48 officers who were elected at the afternoon business session are:

President: Richard V. Curtis, Deadwood, S. D.
Vice President: Don Wessel, Mobridge, S. D.
Secretary-Treasurer: W. W. Towne, Pierre, S. D.

W. W. Towne,
Secretary-Treasurer

NEW YORK STATE SEWAGE WORKS ASSOCIATION

20th Annual Meeting

New York City, January 23–24, 1948

The Twentieth Annual Meeting of the New York State Sewage Works Association was held at the Hotel Pennsylvania in New York City on January 23 and 24, 1948, with 322 members and guests attending.

The program was pointed in particular to the celebration of the twentieth anniversary of the founding of the association. General comments overheard and received by officials of the association clearly indicate that this meeting was among the best and most interesting ever held during the 20 years of the association's existence. Both the technical and entertainment features of the program were outstanding.

The morning program on January 23rd provided a "Symposium on Chlorination of Sewage" which included three interesting and excellent technical papers, as follows:

"Survey of State Department of Health Regulations for Chlorination of Sewage," by Harry A. Faber, The Chlorine Institute, Inc., New York City.

"A Statistical Approach to the Chlorination of Sewage," by Austin Heller, research associate; Herman L. Krieger, research fellow; and Rolf Eliassen, professor of sanitary engineering, New York University, New York City.

"Practical Design and Operation in Chlorination of Sewage," by J. W. Johnson, works superintendent, Buffalo Sewer Authority.

The noon luncheon program was planned particularly to commemorate the founding and the 20 years of noteworthy accomplishments of the NYSSWA. Special tables were provided for the seating of charter members and past presidents of the association, and appropriate comments were made by President Martin in tribute to the association founders and all past presidents. Thirteen of the seventeen living past presidents were present for the ceremonies.

President George S. Russell and Secretary W. H. Wisely of the FSWA were present and made brief talks concerning Federation affairs. The Federation's Kenneth Allen Award, in the form of an embossed certificate, was presented by President Russell to Wellington Donaldson of New York City.

Dean Thorndike Saville, engineering member of the New York State Public Health Council, extended greetings to the Association and made a few remarks applying particularly to his functions and duties on the Council and his interests in advancing not only the standards but also the levels of compensation for members of the sewage works and engineering professions.

Chairman of the Memorial Awards Committee W. H. Larkin with appropriate ceremonies presented the following awards: 1948 Kenneth Allen Memorial Award (NYSSWA award) to Professor C. J. Velz, of Manhattan College, in recognition of his paper "Factors Influencing Self-Purification of Streams"; Lewis V. Carpenter Memorial Award to H. M. Rath, Tallman's Island Sewage Treatment Plant, in recognition of his paper "Tallman's Island Sewage Treatment Works." Channel Samson, of Tonawanda, who was the winner of the 1945 Lewis V. Carpenter Memorial Award, was presented with an embossed certificate attesting to that fact. This latter award had never been formally presented to Mr. Samson because of delays occasioned by the war.

J. C. Brigham, senior sanitary engineer, New York State Department of Health, and treasurer of the NYSSWA, gave an excellent historical review of association activities entitled "Highlights of the Association's First Twenty Years."

The outstanding entertainment feature at the noon luncheon was a lecture by Mr. Allan Johnstone, of Wallace and Tiernan, Inc., entitled "American Sewage Works Practice Reviewed by a Russian Expert." Mr. Johnstone was billed on the program as Dr. Aleksei Ivanov-Kamnev, and it was not until he made his appearance from the wings carefully made up and

dressed as a Russian scientist that many in the audience became aware that Mr. Johnstone's contribution to the meeting was to be pure entertainment.

The afternoon technical program included three excellent papers dealing with industrial wastes pollution and the activated sludge process as follows:

"Industrial Waste Pollution Abatement Program for Buffalo, N. Y.," by George E. Symons, consultant; George F. Fynn, chief chemist; and Howard Brown, research chemist, Buffalo Sewer Authority.

"Pilot Plant for Coke Plant Wastes," by Newell L. Nussbaumer, consulting engineer, Buffalo.

"Practical Results of Step Aeration," by Wilbur N. Torpey, civil engineer, Department of Public Works, New York City.

By courtesy of the Water and Sewage Works Manufacturer's Association, Inc., a social hour was provided for members and guests of the association upon conclusion of its technical sessions.

On Saturday, January 24th, many members joined with members of the American Society of Civil Engineers in an inspection trip by ferry boat around Manhattan Island.

Officers elected for 1948 were:

President: Edwin C. McKeeman, Freeport
Vice President: Paul E. Bardet, New York City
FSWA Director: George W. Symons, New York City
Secretary: A. F. Dappert, Albany
Treasurer: J. C. Brigham, Albany

A. F. DAPPERT,
Secretary

OKLAHOMA WATER AND SEWAGE CONFERENCE

21st Annual Meeting

Stillwater, Oklahoma, January 26–30, 1948

The 1948 Annual Meeting of the Oklahoma Water and Sewage Conference was held at Oklahoma A. and M. College, at Stillwater, on January 28, 1948. As in the past the annual meeting was the outstanding event of the 21st Water and Sewage Short Course. In spite of the adverse weather conditions, 65 registered for the meeting and short course.

The technical program was divided into two main subjects, water and sewage works operation, and reservoir control. The lectures covered each of these subjects thoroughly and were supplemented by laboratory sessions.

The conference dinner and business meeting on January 28 featured an address by V. M. Ehlers, State Sanitary Engineer of Texas and the Vice-President of FSWA, on "The Development of the Texas Water and Sewage Works Operators Licensing Program." Following his address, Mr. Ehlers presented to H. J. Darcey, state sanitary engineer of Oklahoma, the Kenneth Allen Award for outstanding service in the sewage works field.

The conference adopted a resolution presented by Frank Taylor, Oklahoma City, chairman of the Licensing Committee. The resolution provided for a voluntary certification and licensing program for water and sewage works operators together with an examining board to set standards and to examine applicants. Applicants qualifying will be recommended for a license to be issued by the State Commissioner of Health. A provisional license will be issued to all operators, now employed, for 1 year from and after the date of

the first examination held by the Board. Such licenses are to be renewed annually provided progress is made toward qualification for certification. Provisional licenses will not be issued for more than a total of 5 years in any case.

Officers elected for 1948 are:

President: C. E. Moutrey, Tulsa, Okla.
Vice President: Earl Wittmer, Ponca City, Okla.
Secretary-Treasurer: H. J. Darcey, Oklahoma City, Okla.

H. J. DARCEY,
Secretary-Treasurer

TEXAS SEWAGE WORKS SECTION

1948 Annual Meeting

College Station, Texas, February 11, 1948

The Annual Business Meeting of the Texas Sewage Works Section of the Texas Water Works and Sewerage Short School was held Feb. 11, 1948, as part of the 30th annual operators' school at A. and M. College, College Station, Texas. Chairman J. H. Sorrels presided.

Chairman Sorrels outlined all of the awards made available to the Section by the FSWA. He stressed the desirability of increasing section membership in an effort to secure one or more of the membership prizes awarded by the Federation.

The report of the Committee on Certification of Sewage Plant Operators was presented by E. J. M. Berg, chairman. Mr. Berg also introduced, in summarized form, the report of the Committee on Remuneration. It was voted that the summarized findings of this committee be published in the short school proceedings.

A short discussion was held on the emphasis given to sewerage subjects in the programs of the district associations.

Officers elected to serve for the 1948–49 year were:

Chairman: J. B. Burden, San Angelo
Vice Chairman: Irving M. Dietz, Corpus Christi
Secretary-Treasurer: V. M. Ehlers, Austin
Federation Director: J. H. Sorrels, College Station

The usual complete and diversified technical program was offered by the Texas Water Works and Sewerage Short School. The program presented sections on water, sewerage, and general topics. Special out-of-state speakers who participated included George S. Russell, president, FSWA; E. L. Filby, Black and Veatch, consulting engineers, Kansas City, Mo.; A. E. Griffin, director of the Technical Service Division of Wallace and Tiernan Co., Newark, N. J.; Merrill B. Gamet, professor of sanitary engineering, Northwestern University, Evanston, Ill.; and E. E. Talbot, Ruberoid Company, Woodbury, N. J.

At the annual banquet session the following municipalities received awards presented by Dr. George W. Cox, State Health Officer of Texas: Grand Prairie, for the highest percentage of population connected to the sanitary sewer system; Lott, for the greatest ratio of new sewer system connections during the year; Comanche, for making the best use of sewage effluent in irrigation; Corpus Christi, for maintaining the best sewage plant laboratory; El Paso, for making industrial use of its sewage effluent; Big Spring, for maintaining

the most attractive sewage treatment plant; Harris County Water Control and Improvement District No. 11, for having the sewage treatment plant producing the best effluent; El Paso County Water Control and Improvement District No. 1, for completing the greatest improvements to its sewage treatment plant in 1947.

Honorary life memberships were presented to Clyde C. Hays, of Waco, and Ashley G. Classen, of El Paso. A $100 U. S. Savings Bond was presented to Joe B. Winston in recognition of his unselfish and faithful service to the organization.

MRS. EARL R. GOODWIN,
Assistant Secretary-Treasurer

KANSAS SEWAGE WORKS ASSOCIATION

Third Annual Meeting

Wichita, Kansas, March 11–12, 1948

The Third Annual Meeting of the Kansas Sewage Works Association was held jointly with the Kansas Section AWWA on March 11–12, 1948, at the Hotel Broadview, Wichita, Kansas. One hundred sixteen members and guests attended the sessions, which was an exceedingly good number in view of the blizzard which blocked most of the roads in western Kansas the day before the meeting.

At the morning session on March 11, President George S. Russell of the FSWA and President N. T. Veatch of the AWWA presented greetings from their respective organizations. The Kansas Section AWWA secretary-treasurer's report was read by Major C. Hager, following which James B. Arbuthnot, secretary-treasurer of the Kansas Sewage Works Association, presented his report. The session was concluded with a panel discussion on cost trends in water production and distribution, and the expected effect of costs on rates.

The following papers were presented during the afternoon session:

"Historical Development of Sewage Treatment," by George S. Russell, president, FSWA, St. Louis, Mo.

"Sewage Maintenance Practices in Wichita," by George J. Fisher, superintendent of sewers, Wichita.

"Problems of Financing Sewage Treatment," by C. Madison Williams, commissioner of streets and public improvements, Topeka.

"Operation Problems of the Small Sewage Plant Operator," by Lester T. Hagadorn, consulting engineer, Wilson and Company, Salina.

The annual dinner was attended by over 125 members and guests.

The March 12th joint morning session was devoted to discussions of water supply topics. During the afternoon session the problem of financing sewerage systems was discussed by Edwin F. Abels, state representative, 12th District. During this session the Question Box was opened and the questions read aloud. Experiences with the problems raised by the questions were exchanged, to the mutual advantage of all.

Officers elected by the Association for the year 1948–49 were:

Chairman: Myron K. Nelson, Mission
Vice Chairman: Lester T. Hagadorn, Salina
Secretary-Treasurer: James B. Arbuthnot, Lawrence
FSWA Director: E. F. Miltner, Wichita

JAMES B. ARBUTHNOT,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Kentucky-Tennessee Ind. Wastes and Sewage Works Assn.	Chattanooga, Tenn.	Aug. 23–25, 1948
Pennsylvania Sewage Works Assn.	Nittany Lion Inn, State College, Penn.	Aug. 25–27, 1948
New England Sewage Works Assn.	Hotel Viking, Newport, R. I.	Sept. 9–10, 1948
Iowa Sewage Works Assn.	Hotel Kirkwood, Des Moines, Iowa	Sept. 14–15, 1948
Rocky Mountain Sewage Works Assn.	Plains Hotel, Cheyenne, Wyoming	Sept. 15, 1948
Georgia Sewage Works Assn.	Georgia Inst. of Technology, Atlanta, Ga.	Sept. 22–24, 1948
South Dakota Water and Sewage Works Conference	Carpenter Hotel, Sioux Falls, S. D.	Sept. 30–Oct. 1, 1948
West Virginia Sewage and Ind. Wastes Assn.	Stonewall Jackson Hotel, Clarksburg, W. Virginia	Sept 30–Oct. 2, 1948
Virginia Ind. Wastes and Sewage Works Assn.	Hotel George Mason, Alexandria, Va.	Oct. 7–8, 1948
Arizona Fall Conference	Hotel Westward-Ho, Phoenix, Arizona	Oct. 15–17, 1948
Federation of Sewage Works Associations	**Statler Hotel, Detroit, Mich.**	**Oct. 18–21, 1948**
Michigan Sewage Works Assn.	Statler Hotel, Detroit, Mich.	Oct. 18–21, 1948
Missouri Water and Sewerage Conference	Hotel Governor, Jefferson City, Mo.	Oct. 24–26, 1948
North Carolina Sewage Works Assn.	George Vanderbilt Hotel, Asheville, N. C.	Nov. 8–10, 1948

Federation Affairs

DETROIT CONVENTION PROGRAM TAKES SHAPE

Early indications are that the Twenty-first Annual Meeting of the Federation of Sewage Works Associations, to be held at the Hotel Statler, Detroit, Michigan, on October 18–21, 1948, will attract the largest registration ever to attend a Federation convention. The Michigan Sewage Works Association is acting as host to the international organization, and more than forty of its members in the Detroit area are at work on arrangements under the chairmanship of William M. Wallace, superintendent of filtration and sewage treatment at Detroit.

Hotel Accommodations

Those planning to attend the meeting are urged to make hotel reservations without delay. The Hotel Statler, headquarters for all technical and social events, has allocated accommodations for about 600 persons. Requirements above this figure are expected to be met by the Book-Cadillac Hotel, located within walking distance of the Statler.

Requests for reservations should be directed to the hotels—not to Federation headquarters.

Technical Program

Program Chairman F. W. Gilcreas has announced the complete technical program. Topical coverage is unusually comprehensive.

Of general interest will be the papers by Prof. Rolf Eliassen on "Mechanisms of Hydrogen Sulfide Production"; by Dr. A. E. Berry on "Sewage Treatment and Waste Disposal in Ontario"; by Dr. James B. Lackey on "Biology of Sewage Treatment"; by Daniel A. Okun on "A System of Bio-Precipitation of Organic Matter from Sewage"; and by Dr. Willem Rudolfs on "Effect of Synthetic Detergents on Sewage Treatment Processes."

The activated sludge process is the basis for two contributions: "Mathematical Aspects of Bulking Activated Sludge," by Leon S. Kraus, and "Factors Affecting the Efficiency of Activated Sludge Plants," by Prof. William E. Stanley.

One afternoon is to be devoted to an inspection trip of the Detroit and Dearborn sewage treatment plants. Background for the tour will be given in the paper "Design and Operation of the Detroit Sewage Treatment Plant," by W. M. Wallace. Of further significance as to conditions in the Detroit area will be the report by M. Le Bosquet, Jr., on the "USPHS Survey of the Detroit River."

Industrial waste problems are given liberal program time. "The Problem of Waste Disposal from Atomic Energy Operations," by Arthur E. Gorman, will be received with interest. An entire session is assigned to the "Industrial Wastes Forum," at which Dr. F. W. Mohlman will preside. Discussion generators here will be the papers "Dye Plant Wastes and Disposal in Streams," by Dr. V. L. King; "Dairy Waste Disposal," by Prof. E. F. Eldridge, "Waste from Chemical Manufacturing," by Dr. R. W. Hess; and "Indices of Stream Pollution," by Prof. Don E. Bloodgood.

Practical aspects of sewage works operation and maintenance will be given a good share of attention in the paper "Sewer System Operation and Maintenance Procedures at Milwaukee," by Lloyd D. Knapp, and in the "Operators' Forum," which is given a full session. The forum, always a highlight of the program, will be conducted by Ralph E. Fuhrman.

Feature of the Annual Federation Luncheon will be an address by Kenneth A. Reid, Executive Director of the Izaac Walton League of America. A forceful speaker, Mr. Reid will discuss stream pollution control from the point of view of the conservationist.

Social Program

Details of the social events that will lend balance to the FSWA convention are as yet in development. Included will be a Reception-Entertainment on Monday evening, October 17, the Annual Dinner and Dance on Wednesday evening October 19, and a full schedule of special events for the ladies. The Michigan Sewage Works Association will hold its Annual Dinner and Business Meeting on Tuesday evening.

Manufacturers Exhibit

Thirty-six member-companies of the Water and Sewage Works Manufacturers Association placed reservations for exhibit space within two weeks of the announcement of the facilities available. Full occupation of the exhibit area is therefore assured, and an interesting and diversified showing of equipment will be the result.

Announcement to Membership

All Active and Corporate members of the constituent associations of the Federation will be sent early in August a formal announcement of the convention. Contained therein will be further details of value to those planning to attend.

In the meantime, hotel reservations may be placed directly with the Hotel Statler, or the Book-Cadillac if preferred. Mention should be made when requesting reservations that the accommodations are sought for the Federation convention.

MAKE YOUR HOTEL RESERVATIONS FOR THE DETROIT CONVENTION

The Hotel Statler at Detroit, headquarters for the Twenty-First Annual Meeting of the Federation in October, will be able to accommodate most of the out-of-town registrants. Some rooms will also be made available by the Book-Cadillac Hotel, located about three blocks from the Statler.

Requests for room reservations should be addressed directly to the hotel. Note that the technical program will open on Monday morning, October 18, and will close at noon on Thursday, October 21.

WRITE NOW FOR YOUR RESERVATIONS!

Reviews and Abstracts*

Sewerage and Sewage Disposal in 1947. *The Surveyor,* **107,** 115–117 (Feb. 27, 1948); 127–128 (Mar. 5, 1948); 141–143 (Mar. 12, 1948).

In 1947, as in 1946, there was more investigation and planning of sewers and treatment works than actual construction.

It appears that complaints of river pollution are becoming more numerous and serious.

Well planned research and experimental work on sewage treatment problems is needed.

There is increasing interest in joint schemes for sewage treatment. There is no general enthusiasm for large scale centralization, but it is felt that cooperation between authorities can likely bring greater efficiency and economy.

In sewer planning the trend appears to be toward separate systems.

An example of a completely new plant is had in the Colne valley scheme. This works will replace 24 existing works. The design includes sludge digestion, elutriation, vacuum filtration, and flash-drying. It is felt that the dried sludge may find a ready sale as fertilizer.

More attention should be given in design to the division of flow between units.

For some time it has been the practice to return sludge bed drainage, digestion tank supernatant, and excess activated sludge to the raw sewage. There appears to be a growing feeling that waste liquors should be given separate treatment, at least to the degree that they do not cause trouble in the treatment system.

Operation at Bradford may be cited as an example of unusual problems because of the high proportions of greasy textile wastes in the sewage. Acid treatment of the sewage and extraction of grease from the sludge is practiced. Experimental work is under way at this plant along lines of improved operation. An important change at Bradford is the substitution of stone for coal as a filter medium.

More attention is now being paid to better and cleaner methods of removal and disposal of screenings and grit. As to screenings, there is a great deal of interest being shown in means of grinding this material for return to the sewage.

As a means of improving preliminary sedimentation there has been interest shown in flocculation, and there has been a revival of interest in the use of chemicals. At Rotherham a variation of the bioflocculation technique is suggested, wherein 1/6 to 1/3 of the preliminary tank effluent is given complete activated sludge treatment, using the excess sludge to remove colloids from the remainder of the preliminary effluent when treated in a bioflocculation plant. Considerable additional experimental work is required.

Two papers during the year devoted attention to chemical precipitation. One describes work at Halifax on the investigations made to find a possible substitute for sulfuric acid. Chief interest centered on chlorinated copperas, with and without lime. It was found to be more effective than acid, but more costly. It appears that large doses of copperas produced considerable volumes of sludge, which became thinner with increased dosages of copperas.

At Kingston-on-Thames chlorinated copperas reportedly proved more effective and less expensive than aluminum sulfate, previously used.

Regarding settling tank design, it has been the practice to provide larger sedimentation tank capacities than are used on the continent and in America. Much work has been done recently on sedimentation by the Birmingham, Tame and Rae District Drainage Board. It was found that two hours detention period could re-

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publication of public health departments, stream pollution control agencies, research organizations, and educations institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

move most of the settleable solids present. It was concluded that sedimentation capacity was more effective when used in one stage than when worked as a two-stage system.

There seems to be a general opinion that effort should be made to increase the efficiency of final sedimentation, particularly for effluent from trickling filters.

Much consideration is being given to the various methods of filter operation. Recirculation of effluent is attracting a great deal of interest. Further observations at Sheffield have confirmed earlier conclusions on the efficiency of recirculating nitrified effluent in curing filter ponding.

The Loughborough sewage works are to be reconstructed to provide means of recirculating effluent. It is proposed to periodically circulate effluent through the filters without sewage. Large scale experiments have indicated that the existing filters can handle double the present flow by use of this procedure.

Interest has been shown in the use of D.D.T. and Gammexane in the control of filter flies. The report of the Water Pollution Research Board for 1939–1945 contains a great deal of information on the use of these products. It appears that either chemical (but more particularly Gammexane) is likely to be much more economical than older means of control. Caution must be used however, because of the toxic effects of these chemicals on stream life. Tests on goldfish carried on in America indicate 40 per cent mortality after 6 days in a concentration of 1 in 10,000,000.

More attention is now being given to mechanical and more compact methods of sludge disposal. No general enthusiasm has been aroused by experimental work with vacuum filtration. A drawback to the use of filters is the cost of ferric chloride. This material is more costly than in the United States.

Plants producing a sludge easy to handle, and which works into the soil well, have little difficulty in disposing of the material. The fuel and power situation has been an inducement for the utilization of digester gas. Plants recovering grease are having no trouble in disposing of this material.

The possibility of dangerous atmospheric conditions arising in sewers carrying cyanide wastes was studied at West Middlesex. The maximum safe concentration appears to be about 10 p.p.m. cyanide (as HCH). It was found that concentrations of 5 p.p.m. ruined the working of an experimental activated sludge plant. Concentrations as low as 1 p.p.m appear to have a detrimental effect on biological treatment processes.

T. L. HERRICK

Intensification of Sewage Purification. *The Surveyor,* **106**, 653 (Dec. 19, 1947).

There has been a general trend in sewage treatment in the direction of more efficient use of ground area. Better design and use of mechanical equipment for sludge removal has greatly reduced the sedimentation tank capacity required. Compactness in the biological stages has been obtained through the progressive steps of land treatment, sand filters, trickling filters, and activated sludge.

Recent developments in biological filtration indicate that this process may not demand much more space than the activated sludge process. In the field of sludge disposal, digestion and other processes have reduced the drying-bed area required. While economy of area and compactness do not always mean savings in first cost or maintenance cost, it is usually desirable to keep the plant within a small area.

The usual detention period provided in sedimentation tanks in this country lies in the range between 8 to 12 hours, while 2 hours is the usual period allowed overseas. Experimental work by the authors on various types of tanks employed by the Birmingham Tame and Rea District Drainage Board indicated "that a sedimentation tank which is reasonably well designed and operated can effect satisfactory removal of solids with a detention period of about two hours."

Work has recently been done to increase the input of oxygen by the Sheffield type bio-aeration process. This has been accomplished by using triangular paddle blades instead of rectangular, and by increasing the speed of rotation. It appears that the authors have added about 50 per cent to the efficiency of the bio-aeration process. This means a saving in first cost

and area, and it appears that the power requirements of the bio-aeration process may now be about the same order as those of the other activated sludge processes.

Results on nitrification and recirculation of trickling filter effluent during the last 4 years have confirmed the promise of the earlier investigations on the cyclo-nitrifying filter. The persistence of nitrification once it is established in a filter, and the effectiveness of nitrified effluent in curing filter ponding is pointed out.

T. L. HERRICK

Preparation of Sewerage and Sewage Disposal Schemes for Rural Areas. By A. ROCK. *The Surveyor,* **107,** 111–112 (Feb. 27, 1948).

The steps necessary in preparing a sewerage and sewage disposal scheme for a rural area are preliminary investigations, design of the scheme, and preparation of plans for submission to the Ministry of Health for approval.

In making the preliminary investigation the best maps of the area should be used to determine the site or sites for disposal works. It must be determined whether or not the stream will provide sufficient dilution.

In general, it is not economical in rural areas to provide a comprehensive scheme to serve widely separated areas.

The separate sewer system is best suited to rural areas. Water from highways is usually dealt with by ditches and watercourses. In design, the water consumption per capita and the population to be served must be determined. The Ministry of Health suggests 100 gal. (Imp.) per house per day. Probably a better figure is 30 g.p.c.p.d. and an average of 4 persons per house.

In design of the treatment works there is a wide choice in type of works to install. It is largely a matter of probable cost and degree of treatment required. The use of trickling filters is recommended for small installations rather than activated sludge, as the latter is high in operating and maintenance costs.

T. L. HERRICK

Wartime Treatment of Sewage and Sludge Disposal. By F. OLIVER. *The Surveyor,* **105,** 341–342 (May 3, 1946); **105,** 383–385 (May 17, 1946); **105,** 409–410 (May 24, 1946).

The population of Harrogate before the war was 44,500 but during the war the population increased to about 58,000. The increased load on the two sewage treatment plants made certain improvements essential. These included installation of rotary distributors on the trickling filters and the construction of an earth, sludge digestion lagoon.

The efficiency of the filters was substantially improved by the installation of the distributors and consequently no increase in the filters was necessary.

The sludge digestion lagoon which was constructed in 1943 is 192 ft. by 115 ft. in plan with a working depth of 6 ft. and provides a capacity of 4.5 cu. ft. per person based on a tributary population of 30,000. The detention period is approximately 3 months. Provision was made for seeding and sludge recirculation. This digestion lagoon reduced sludge handling costs. No analyses are reported and the author states that the characteristic tarry odor and black color are taken as a guide for controlling discharge operations.

PAUL D. HANEY

Some Modern Developments in Sewage Disposal. By C. R. DEELEY. *The Surveyor,* **105,** 545–547 (July 12, 1946).

The discussion given in this paper centers around the problems encountered in the treatment of sewage from the City of Coventry. The rapid growth of this city and consequent need for plant extensions, the somewhat difficult character of its sewage, and the general advances in sewage treatment practice have produced a number of problems and led to several interesting experiments during the past 20 years.

One experiment involved dividing the activated sludge plant into five separate units and for a period of several months giving partial treatment in the first unit followed by full treatment in the remaining units. It was found that when operated in this way the total capacity of the plant was increased by 50 per cent.

In another experiment it was found that the effluent from a trickling filter plant could be substantially improved by passing it over land.

Introduction of recirculation facilities at the trickling filter plant did not result in any striking improvement in the quality of the effluent but did lead to improvement in the condition of the filters. Ponding was almost entirely eliminated.

Experiments on sludge heating led to the conclusions that the existing sludge digestion plant would be capable of dealing with twice the normal quantity of sludge if full scale heating facilities were installed, and that a high daily yield of gas containing 70 per cent methane (670 B.T.U. per cu. ft.) would be obtained.

PAUL D. HANEY

Servicing a Sewage Works. BY W. F. FREEBORN AND A. A. KIRKBRIGHT. *The Surveyor,* **105**, 567–570, 585–586, 713–717 (July 19, July 26, Sept. 13, 1946).

This paper contains discussions of those general services which assist in the efficient operation of sewage works.

Materials and Hired Services. The maintenance of a first-class storeroom service is essential if the works is to function satisfactorily. The authors develop this phase of the subject by discussing storeroom layout, location, construction and operation.

Transport and Appliances. The number and class of vehicles will depend upon the normal work volume but in determining this number some allowance should be made for the fact that certain vehicles will be out of service for repairs at times. There may be a tendency to overload light trucks and provision of heavier trucks originally may save on maintenance. The combined driver-mechanic is seldom an economic feature. A competent mechanic should be employed wherever possible and prevention of breakdown rather than repair should be his aim.

Plant and Appliances. Wherever heavy machinery is to be handled overhead, traveling hoisting equipment should be provided. For general use in dealing with light loads a mobile crane is desirable. Such equipment has possibilities for efficient use but its use will call for stronger roads and bridges and ample space for maneuver.

Welfare of Employees. In planning or replanning sewage works the following should be considered: space for locker rooms, space and means for drying wet clothing, adequate washing facilities, facilities for eating, and housing of personnel.

Plant Surroundings. The authors note that too often the sewage treatment plant construction budget contains no item for cleaning up and improving the plant site, these important items being left to the ingenuity of the plant superintendent. Every sewage works has areas which should be planted with trees and shrubs or grass. In planning the various plantings the superintendent should consult with someone experienced in this field. Paths should be laid out in direct lines to avoid disfiguring "short cut" patterns.

Workshops. Combination of workshops and storerooms in one main service building has many advantages.

Finance. In discussing budgets the authors suggest that a large number of small budgetary items should be avoided. By avoiding small and detailed budget items the superintendent is given a certain amount of freedom within his spending authority.

It is a sound financial policy to provide depreciation funds so that when equipment is worn out funds are available to replace it.

The most satisfactory means of meeting the statutory requirement that lifting tackle, pressure vessels, etc., be regularly inspected and tested is to arrange for it to be carried out by an insurance or other company specializing in this type of business. The question of insurance for plant machinery arises. Some sewage works authorities build up their own insurance reserves but the relatively low premiums quoted by insurance companies usually make this course unattractive. Furthermore the insurance companies provide an important service in the form of inspections and reports on the plant covered.

Staff and Future. With increasing mechanization the number of employees at sewage works decreases but at the same time a higher quality of worker is required. Since skilled labor is in short supply it is necessary to conserve labor and make machinery do as much work as possible.

PAUL D. HANEY

Sludge Pumping. By M. R. Vincent Daviss. *The Surveyor,* **105**, 527–531, 607–609, 623–624 (July 5, Aug. 2, Aug. 9, 1946).

This paper is a discussion of the main features of the various types of sludge pumps together with their characteristics and suitability for particular conditions of pumping. Of the types in use the majority are reciprocating and centrifugal, and the paper is limited to a discussion of these types.

Diagrammatic sketches of pumps and characteristic curves for centrifugal pumps are given.

In the design of sludge pumping stations a major consideration should be to reduce the suction head to a minimum. One important reason for this is that centrifugal sludge pumps are relatively slow running and, therefore, less efficient for producing and maintaining vacuum. Another reason is that under reduced pressure gases may be released from the sludge. Furthermore, placing the pumps at a low level also eliminates the priming problem.

Suction and discharge mains should wherever possible be laid with a rising gradient in the direction of flow to avoid air locks. If a reversal of the grade is impossible provision should be made for gas release at the highest point.

In discussing friction losses in sludge pipes, the author states that for sludges having a moisture content of less than 98 per cent water it is the practice to take friction as two to four times the friction loss for water.

Centrifugal sludge pumps are suitable for use with thin sludge, but for thick sludge reciprocating pumps are recommended.

In the discussion of this paper it is noted that friction head loss for 90 per cent moisture sludge flowing in clean mains may be 100 times that of water.

Paul D. Haney

Large Scale Experiments on the Sedimentation of Sewage in Rectangular Tanks.* By S. H. Jenkins, C. H. Hewitt, and C. E. Winsor. *Institute of Sewage Purification,* 17 pp. (Dec. 4, 1947).

The experiments described in this paper are concerned with rectangular sedimentation tanks operated at high rates of flow. A knowledge of the limitations of such tanks is desirable and such knowledge is scanty. Retention times (British practice) may vary from 6 to 7 hours up to as much as 15 to 18 hours. American and European practice is to use much shorter periods.

Sedimentation theory can point toward the best conditions for design but tanks cannot be designed on a purely theoretical basis until more is known about settling velocities of sewage solids under varying circumstances.

In the experiments reported in this paper sampling was done at 15- to 20-min. intervals. Usual analyses were organic nitrogen, total suspended solids (Gooch crucible method), and settleable solids (special procedure). Arbitrary standards of tank effluent quality were established based on settleable solids: up to 30 p.p.m., well settled effluent; 30 to 50 p.p.m., moderately well settled; over 50 p.p.m., badly settled.

Results of experiments indicated that sedimentation in one stage was much more effective than sedimentation in two-stage tanks of poor design and long retention, and the authors state that a single tank is probably more efficient than two tanks in series of combined capacity equal to the single tank. It is also stated that if two-stage tanks are not generally regarded as inefficient, it is probably because of a wide margin of safety used in their design.

No clear evidence was obtained in these experiments that sludge once settled out was disturbed by the flow of sewage even when large flows were allowed to pass over an appreciable depth of sludge. The inference is that in mechanically cleaned tanks, the depth could be reduced without loss of efficiency provided that the mechanism does not disturb the sludge. Here the authors note that both Hazen (in 1904) and Camp (in 1945) called attention to the importance of area rather than depth in sedimentation basins.

Variations in the degree of flocculation were noted. Flocculation may be the result of inlet turbulence, and this could explain the good performance obtained from some tanks of poor design. If it is flocculation which causes organic matter to become settleable, it may be argued that the reason why settleable solids are present

* A preprint.

in a tank effluent is because the reduced concentration near the outlet has lessened the possibility of collisions occurring.

The authors conclude that the total suspended solids test does not provide a reliable measure of the performance of a sedimentation tank since a tank can remove only what is settleable, and much of the material in raw sewage will not settle in 2 hours of quiescence.

In one series of tests sewage containing industrial waste and secondary sludges was treated in a mechanically cleaned tank. No deterioration in the quality of the effluent was caused by a sudden three-fold increase in the normal flow. Excellent results were obtained at retention periods of 1.8 to 1.9 hours.

In another series of tests a highly industrial sewage was passed through a tank with poorly arranged inlets and turbulent conditions due to baffles and sludge accumulations. The performance of this tank was moderately good with retention periods of 1.2 to 1.8 hours, and even with retention periods as low as 0.7 to 0.8 hour removal of over 50 per cent of the settleable matter was obtained.

In a third series of tests primary tank effluent was mixed with surplus activated sludge, aerated, and then passed into rectangular secondary tanks. With 7.8 hours retention time the results were excellent, and they were acceptable at 1.4 hours. There was, however, a tendency for the sludge to rise when the suspended matter was contributed mostly by the activated sludge. When the suspended matter in the influent was high the effluent suspended matter was excessive.

Although the authors refer frequently to the retention time of settling tanks, they emphasize that they do not regard it as an all-important factor in tank efficiency.

Twenty-five charts and nine references are included.

PAUL D. HANEY

Experimental Work Leading to an Increased Efficiency in the Bio-Aeration Process of Sewage Purification.* BY JAMES H. EDMONDSON AND S. R. GOODRICH. *Institute of Sewage Purification,* 19 pp. (Dec. 3, 1947).

* A preprint.

Early experiments by John Haworth on the treatment of the Sheffield city sewage led to the development of a paddle stirrer for use in connection with the aeration of sewage. This paper is concerned with large scale experiments on the efficiency of various types of paddle wheels, blades, and rotating drums when used for sewage aeration. Some of the experiments were conducted in a specially constructed experimental channel having a water capacity of 16,000 gallons. City water was used in these experiments. Deoxygenation of the water was accomplished by means of lime and ferrous sulfate.

Large plant-scale experiments were conducted at a bio-aeration plant. The failure of this bio-aeration plant was attributed to insufficient oxygen absorption by stream flow surface aeration, and the great improvement in plant performance after part of the aeration tank was equipped with paddle wheels during the course of these experiments serves to emphasize the importance of the paddle wheel as an aerator.

Paddle wheels used varied in diameter from 7 ft. to 8 ft., 1 in. The conclusions drawn from the experimental results were: (1) the best results were obtained when the paddle speed was 30 r.p.m.; (2) the highest efficiency was obtained with a triangular paddle blade; (3) oxygen input varies with the depth of paddle blade immersion.

The bio-aeration plant studies indicated that the installation of paddle wheel aerators would increase the plant capacity by 60 per cent and that the horsepower required to remove 1 lb. of B.O.D. would be 0.37.

Complete details of the experimental procedure and the method of computing oxygen absorbed during aerator operation are given in an appendix.

PAUL D. HANEY

A Control Chart for Bacterial Coloney Counts. BY C. L. HANNAY. *Proceedings of the Society for Applied Bacteriology,* No. 2, 1946.

A method of preparing a chart for the statistical control of the accuracy of the bacterial coloney counting method is presented and discussed. An example is

given, together with sample calculations, which illustrates the use of the chart.

S. C. MARTIN

Typical Design of a Sewerage System (for Cassipore, India). By P. C. BOSE. *Journal of the Association of Engineers (India)*, **23**, 2, 99 (June, 1947).

This paper gives a history of the development of the Cossipore sewerage system together with a description of the existing system and a discussion of related factors such as area, population, water supply, etc. Design factors for proposed sewerage improvements are also discussed.

The chief value of the paper lies in its presentation of current design practices employed in India. Of less value, but of considerable interest, is the discussion pertaining to the development of the existing drainage and sewerage systems.

S. C. MARTIN

Industrial Wastes—Brass and Copper Industry. By WILLIAM S. WISE, BARNETT F. DODGE, AND HARDING BLISS. *Industrial and Engineering Chemistry*, **39**, 632–636 (May, 1947).

The first part of this paper discusses the Connecticut law in regard to pollution of waterways and states "that any order requiring the abatement of pollution shall specify the particular system or means to be used and that the cost of installation, maintenance, and operation shall not be unreasonable or inequitable."

The paper also gives a short history of the brass and copper industry in the U. S. and the proportion of this industry in Connecticut.

A section is devoted to manufacturing operations.

The volume of water-borne wastes from this industry is large. Fifty tons of finished metal may require from 3,000 to 6,000 gal. per hr. of water for pickling and bright dipping. Large quantities of water are used in other operations and result in oil-bearing wastes.

The liquid wastes from pickling operations at a large brass plant in Connecticut showed the following composition. These samples were collected from each of 8 pickle tubs having a capacity of 1,100 gal. and indicate the variation in composition just prior to dumping.

	Grams per Liter
Sulfuric acid	59.7 to 163.5
Copper	4.0 to 22.6
Zinc	4.3 to 41.4
Chromium, total	0 to 0.56
Iron	0.1 to 0.21

Samples from each of 9 bright-dip tanks (capacities 300 to 1,100 gal.) prior to dumping showed:

	Grams per Liter
Sulfuric acid	5.6 to 85.8
Copper	6.9 to 44.0
Zinc	0.2 to 37.0
Chromium, hexavalent	4.3 to 19.1
Chromium, total	13.5 to 47.7
Iron	0.03 to 0.36

The analyses of samples collected from rinse water drains over 24 hours showed hourly variations and "calculations made from these analyses and volumes showed acid and total metal loss from pickling operations as follows":

	Acid (%)	Total Metals (%)
In rinse waters	88.5	90
In spent pickle	9.6	3.8
In spent bright dip	1.9	6.2

"This survey . . . revealed the surprising fact that the major portion of the pollution load, and by far the greatest acid and metal loss, occurs in the dilute wastes."

These wastes are detrimental to fish life if the water in the receiving stream is soft, and the pH of the wastes is more acid than 6.0. "Concentrations of copper, chromium, zinc., etc., greater than about 2 p.p.m. are usually considered lethal to aquatic life." These wastes also affect the natural processes of self-purification of streams. Certain concentrations of these wastes cause break-down of sewers.

A description is given of a pilot plant which was operated in 1934–35 and which treated strong wastes combined with dilute wastes. The plant had a capacity of 10 gal. per minute. Since the operation of this pilot plant research has been directed towards the regeneration of the strong chromate waste pickle liquor for direct return and re-use, and concentration of the metals in the more dilute rinse waters to the point where they could be mixed with the spent pickling liquors for further treatment and recovery. The application

of the ion-exchange principle is also being considered.

A flow sheet is shown for the regeneration of the strong chromate waste pickle liquor.

A flow diagram is given for the treatment of brass and copper mill wastes.

H. GLADYS SWOPE

Industrial Wastes. Canning Industry. By E. F. ELDRIDGE. *Ind. and Eng. Chem.*, **39**, 619–624 (May, 1947).

Wastes from food which is preserved in hermetically sealed containers and sterilized by heat are the only ones considered in this paper.

The history of canning is briefly discussed. In the last census there were over 3,000 canneries in the U. S., and about 75 per cent of these pack fruits and vegetables.

In the canning industry each raw product produces a different waste and requires special variations in methods of waste disposal.

The author considers only three canning operations; tomatoes, peas and corn. Each method of canning these vegetables is discussed and a flow diagram given.

A table is shown which gives the volume and concentration of cannery wastes. The author states, however, that the table values are average values and "should be used only as guides and should not be depended upon for the design of waste disposal facilities." (Table I.)

Cannery wastes are seasonal, and since canneries are more generally located near the source of supply and are operated for one or two products, biological treatment of the wastes is not usually feasible.

"The following are the combinations adapted in general to cannery wastes: (1) screening; (2) screening and chemical precipitation; (3) screening, chemical precipitation, and sand filter; (4) screening, chemical precipitation, and lagooning; (5) screening and biological filtration; (6) screening, biological filtration, and lagooning; and (7) screening and lagooning."

Screening is a "must" for cannery wastes except for the water from boilers and coolers. Rotary or vibrating type screens are generally used. "A 40-mesh screen is most commonly recommended; however, if chemical precipitation is to

TABLE I.—Volume and Concentration of Cannery Wastes

Product	Waste Vol. (gal. per case No. 2 cans)	Suspended Solids (p.p.m.)	B.O.D. (p.p.m.)	B.O.D. (Lb. per case of No. 2 cans)
Vegetables				
Beans, green	42	—	400	0.140
Beans, wax	26	60	240	0.052
Beans, lima	50	—	450	0.188
Beets, red	25	1,120	2,500	0.520
Carrots	23	1,830	1,110	0.213
Corn	25	980	3,000	0.625
Corn ensilage liquor	—	—	27,000	—
Peas	25	2,800	2,400	0.500
Pea ensilage liquor	2	—	35,000	—
Pickles	—	200	3,000	—
Potatoes	—	990	220	—
Spinach	20	3,500	6,000	1.00
Tomatoes, whole	15	190	570	0.071
Tomatoes and puree	7.5	950	2,916	0.182
Fruits				
Apricots	55	260	380	0.208
Cherries	40	20	750	0.250
Citrus fruit, sections	50	268	1,860	0.775
Citrus fruit, juice	50	171	343	0.143
Grapes	—	1,650	720	—
Pears	51	310	450	0.191

follow the screen, a 28-mesh may be used. The capacity of the screen must be such as to handle the maximum rate of flow of that waste which is most difficult to screen."

As biological treatment is neither feasible nor economical for a cannery which operates only a portion of the year, chemical precipitation is used, and the fill-and-draw method generally employed. The minimum number of tanks is two, on the fill-and-draw basis. "The capacity of each tank is based on the following considerations: (a) A 30-min. period is required for the addition of the chemicals and flocculation. (b) A minimum period of 2 hours is required for settling. (c) One to 1.5 hours are required for the drawing of sludge and the discharge of the treated waste. (d) This means that the capacity must be such as to allow 4 hours for the preceding operations of the tank or tanks out of service. When two tanks are used, each should have a capacity for 4 hours of maximum flow of waste." . . .

. . . "However, in applying chemical treatment a study should be made at the cannery to determine the most effective chemical for the specific waste. The dosage required will vary throughout the period of treatment, and intermittent tests are necessary for control of the process."

Where more complete treatment is required sand filtration may be used. The recommended rate of filtration is 2 gal. per sq. ft. per minute. The filter should be equipped for backwashing.

If biological treatment is necessary, then a recirculating type of filter is recommended. A plan of such a filter is shown. "The volume of media should be such as to provide a loading factor of 1 lb. of B.O.D. per cu. yd. per day."

Lagooning of cannery wastes is practiced but unless these wastes are lagooned in very isolated areas odor control will have to be practiced. For this purpose sodium nitrate is used.

A table is given showing the estimated cost of cannery waste treatment based on prewar prices.

H. Gladys Swope

Bibliography on Chemical Wastes. By R. W. Hess. *Industrial and Engineering Chemistry,* **39,** 676–682 (May, 1947).

This bibliography covers the literature from the period of 1937 to April, 1947. The headings under which the references are given and the number of such references are:

Water pollution and its control—45.
Water pollution and the law—7.
Organization for pollution control—5.
Reviews—20.
Regional problems—42.
Water sanitation—4.
Natural purification—8.
Toxicity of wastes to aquatic life—8.
General treatment of wastes—53.
Biological treatment—5.
Acid wastes—7.
Cyanide wastes—10.
Phenolic wastes—9.
Metallic wastes—references given to 11 different metals.
Miscellaneous wastes—references given to 12 different wastes.
Company treatment—4.
Mixing industrial wastes with sewage—16.
Analytical methods—4.

H. Gladys Swope

Industrial Wastes in the Packing House Industry. By F. W. Mohlman. *Industrial and Engineering Chemistry,* **39,** 637–641 (May, 1947).

"Wastes from the packing house industry originate in the various departments, beginning with the stockyards, then from the killing floor, washing of the carcass, washing and cleaning of entrails, paunch manure, blood drainage, tankage, evaporators, hide drainage, hog hair removal, pickling, cooking, rendering, and general cleanup . . . the larger and more complex the packing house, the more effort is made to recover byproducts and the less blood, meat, extracts, and fat are lost. Paunch manure is sometimes screened, but soluble contents are not retained, and therefore paunch manure screening does not greatly reduce the over-all wastes. Blood should always be dried and recovered, tankage should be evaporated and sold, rendering losses should be prevented by proper grease-recovery equipment, and solid particles of meat, hair, and offal should be screened and removed."

Unit losses are discussed and it is pointed out that such losses have been re-

TABLE II.—Unit Packing House Losses, Chicago

Type of Kill	Amt. of Kill (tons per 24 hr.)	Water Used (gal. per ton)	Pounds per Ton			
			B.O.D.	Susp. Solids	Nitrogen	Grease
Hogs	51	5,500	36.0	24.0	5.34	1.80
Hogs	114	2,200	30.1	18.2	2.58	4.61
Mixed	127	2,600	25.4	9.1	4.05	2.88
Hogs	139	4,900	26.2	19.6	2.50	5.66
Cattle	148	1,900	41.5	29.6	4.47	1.35
Cattle	165	2,800	31.4	29.5	4.02	3.58
Cattle	168	2,000	21.0	19.9	2.04	2.01
Mixed	185	2,800	39.4	18.8	5.18	1.20
Hogs	190	4,500	19.5	14.3	2.93	0.54
Mixed	303	4,600	33.4	29.9	4.37	4.00
Cattle	397	6,200	20.0	22.0	2.16	1.10
Mixed	429	6,500	29.4	26.5	3.41	3.00
Mixed	661	2,600	13.0	12.5	1.58	1.00
Mixed	680	8,700	38.5	44.3	4.20	4.20
Average		4,130	28.9	22.7	3.49	2.64

lated to head of kill as "hog unit," but that a more useful unit is per ton of live weight. Although this weight varies, the value that can be approximated is obtained by using 950 lb. per head of cattle, 210 lb. per calf, 260 lb. per hog, and 90 lb. per sheep or lamb.

A table is given showing the slaughter of cattle and hogs in public stockyards of larger cities for 1944; another for Federal inspection data on livestock kill, 1930–45; and another for the total U. S. kill, tonnages, and population equivalents. The unit packing house losses for Chicago are shown in Table II.

The data in Table II were "based on surveys of at least two weeks each, with installation of weirs and automatic head gages, samples taken every 15 min., analyses of 12-hr. composites, computation of pounds lost per day, statistics on head and weight of kill, and computation of losses per ton of kill."

Grease separators should not discharge more than 0.2 lb. skimmable grease per ton of kill. Nitrogen losses indicate poor operation in the tankage house, killing floor, blood recovery, and cook house. Multieffect evaporators should be installed to handle each day's production of tank water.

For final treatment of packing-house wastes the various steps available are: "Coarse screens, fine screens, sedimentation (or vacuator), chemical precipitation, high-rate trickling filters, activated sludge, low-rate trickling filters, chlorination, and dilution."

Trickling filters preceded by a washable high-rate filter have proved most suitable for packing house wastes.

"The problem is severe, as wastes have B.O.D. up to 1800–2000 p.p.m., suspended solids of 1000 to 2000 p.p.m., and more than 100 p.p.m. nitrogen."

A flow diagram of the sewage treatment plant for a large packing house in Sioux Falls, South Dakota, is shown.

Sixteen references are given.

H. Gladys Swope

Poisonous Effluents. Editorial. *The Chemical Age* (London), **57**, 779 (Dec. 20, 1947).

"The River Boards Bill, now receiving the attention of the House of Lords, has not come before its time. Although it does little more than enable the Minister of Health and Agriculture to set up river boards which shall conserve water resources and deal with river pollution, land drainage, and fisheries, the efforts may be far-reaching. In lands where there are wide tracts of open country it is still permissible, though not defensible, to pollute the atmosphere and the water courses at will. In an island so densely populated as Britain, such things obviously cannot

be permitted. Every works should find a means for rendering its effluents harmless, or better still, of putting them to some useful purpose.

"The harm that is done by industrial effluents discharged into rivers in this country is immense. Estuary pollution . . . may prevent migratory fish from moving upstream, and in this way we have lost a great deal of potential food, notably salmon. Pollution in other parts of the rivers and streams kills whatever fish normally live there and destroys the amenities of the countryside. . . .

"It is true that research has not yet caught up with pollution, especially by industrial effluents, in spite of the good work of the Water Pollution Research Laboratory. . . . Industry must not wait for the Department of Scientific and Industrial Research to do something. The purification of each industry's effluents should be a matter for the industry itself. The gas industry, which today has no effluent problem, is an example of how this can be done. We trust that no legislation will be necessary; there is too much compulsion already."

RICHARD D. HOAK

Incineration Solves a Waste Disposal Problem. *Chemical Engineering,* 55, 110–111 (March, 1948).

Sharp expansion of the output of the Nutley, N. J., plant of Hoffman-La Roche, Inc., manufacturers of synthetic vitamins, pharmaceuticals, and fine chemical specialties created a serious industrial waste disposal problem. However, close cooperation with public sanitation authorities coupled with engineering initiative produced a successful solution in the form of an incineration installation.

One of the plant processes produces an alkaline liquor containing organic polysulfides which can best be described by its plant name of "stink" liquor. Initially this waste's volume was 500 gal. daily but the wartime expansion program increased the volume to about 1,200 g.p.d. making it impossible to use public sewer system as a means of disposal. Enlarging the sewer connection and lime treatment of the waste did not solve the problem and the company was ordered to find a new disposal method for this liquor.

An attempt was made to cart the liquor in drums or a tank truck to a private dump, but the character of this waste liquor was such that within 5 months dumping privileges were withdrawn successively at 6 different dumps. Chlorination was next tried but this, while successful in rendering the waste satisfactory for discharge to the public sewers, was expensive and difficult to carry out. Consequently the incineration method was studied. Pilot plant tests showed that the liquor could be evaporated and incinerated in the presence of about 70 per cent excess oxygen at temperatures above 850° F. This produced an inoffensive mixture of sulfur dioxide and carbon dioxide which could be easily dissipated from a stack of medium height, and it was decided to combine incineration of the liquor with a part of the plant's trash and cafeteria garbage.

A modified type of Hiler garbage incinerator was constructed. Two special features of the furnace adapt it to the requirements of this installation. The crown was intentionally weakened to serve as an "explosion hatch" in case explosive materials should accidentally be introduced with the trash, and an enlarged combustion chamber between the bridge wall and the stack breeching was provided into which the liquor is sprayed for evaporation and combustion.

Since much of the waste to be consumed contains too large a quantity of moisture to support its own combustion, additional heat is provided by burning gas and oil.

Temperatures near 900° F. are closely maintained regardless of the rate at which trash is charged by an automatic control system. Incineration of the liquor requires about 4 to 6 hours per day and leaves only a few shovelsful of solid deposit for removal from the access doors. No destruction of firebrick is experienced as long as a satisfactory spray is produced. The liquor is pumped to the incinerator from underground tanks. The special nickel spray heads produce a solid cone spray and are located on both sides of the combustion chamber. Six photographs.

PAUL D. HANEY

Waste Treatment Plant of Eastman Gelatine Corporation. By A. C. Bolde. *Journal of the Boston Society of Civil Engineers,* **34**, 331 (Oct., 1947).

Wastes from this plant are discharged into the Peabody, Mass., municipal sewers, thence to the South Essex sewerage system. Ultimate disposal is accomplished by pumping to a deep-water outfall in Salem harbor. Large amounts of caustic lime in the wastes were found to be partially responsible for scale formations on the inside of the main sewers of Peabody, the South Essex system, and Salem.

A process was developed to remove the caustic lime. It involves passing flue gas through the wastes, the carbon dioxide in the gas combining with the calcium hydroxide to form calcium carbonate, which is precipitated. Flue gas is obtained from the stacks of industrial plants. It is cleaned to remove soot and then compressed.

The South Essex Sewerage Board has adopted a regulation prohibiting the discharge of wastes containing more than 75 p.p.m. of caustic lime. The plant of the Eastman Gelatine Corporation is the largest of nine built for treating such wastes.

The new plant was built to replace one which had become inadequate. It consists of a 90-ft. diam. primary settling tank, a carbonating tank 100 by 40 by 12½ ft. deep, and a 60-ft. diam. secondary settling tank.

Analyses made during the operation of a pilot plant in 1945 showed a pH of 10.6 and a caustic alkalinity of 5,600 p.p.m. in the settled wastes. The carbonated effluent had a pH of 6.8 and a caustic alkalinity of zero.

T. L. Herrick

Grit and Grease Chamber at Salem and Peabody. By Frank L. Flood. *Journal of the Boston Society of Civil Engineers,* **34**, 332 (Oct., 1947).

In the city of Peabody, Mass., there was a total of 94 industrial establishments in 1943, and 56 of these were leather-processing plants. Large quantities of heavy solids and grease were discharged into the trunk sewer from these plants, and it was found impossible to keep the sewer sufficiently free of deposits and incrustations to maintain adequate sewer capacity.

In 1945 the legislature passed an act enabling the provision of a grit and grease chamber at the Peabody-Salem line. At that point the sewer is 52 in. in diam., and it increases in size to 72 in. in passing through Salem.

Two channels are provided, each about 99-ft. long, 16-ft. wide and 14-ft. 8 in. maximum water depth. The detention period is 22½ minutes at the design flow of 11½ m.g.d. Drainage connections are provided for drawing liquor from above the sludge and for draining the channels. They are used in conjunction with two 400 g.p.m. pumps.

Floating scum and grease will be held in the channels by means of baffles. It is contemplated removing this material without taking all of the channels out of service at one time. One channel at a time will be taken out of service for removal of sludge and grit.

A ½-yard clamshell bucket will be used to remove sludge, grit, and scum. The bucket will dump directly into trucks which can be operated on a truckway along one side of the channels. The channels and loading platform are covered. Water tight trucks will be used. The material will be hauled to dumping grounds until such time as incineration facilities are available.

T. L. Herrick

Industrial Utility of Water in Pennsylvania: Chemical Characteristics of Surface Water 1944 to 1946. Pa. Dept. Commerce, State Planning Board, *Publication 17* (August, 1947).

Recognizing the need of industry for adequate and reliable data on the chemical quality of water in Pennsylvania streams, a study was made to obtain systematic records of the chemical characteristics of surface waters throughout the State, and to consider the factors that affect water quality.

The study was divided into a number of phases, including low-flow, high-flow studies; daily sampling-station studies; cross-section studies; unit basin studies; and miscellaneous studies. Each of these phases is discussed separately. There is also a discussion of the source and significance of the chemical and physical char-

acteristics of natural waters, and of the methods of analysis employed.

The major part of the volume is given over to tabulations of the analytical data collected, expressed both as parts per million and as equivalents per million.

Copies of this publication are available on request to the Pa. State Planning Board, Harrisburg, Pa.

RICHARD D. HOAK

Organization and Method for Investigating Wastes in Relation to Water Pollution. MANUAL SHEET W-1. BY MANUFACTURING CHEMISTS' ASSOCIATION OF THE UNITED STATES. Adopted 1948, 7 pp.

The first section of the manual outlines the general problem of water pollution and summarizes the present status of state and federal legislation.

The second section presents a complete general guide for an efficient attack on industrial waste pollution control. The problem is considered from the standpoint of administration, new product development, engineering design of new plants or additions to old ones, and plant operation.

Administration is warned that pollution abatement requires the expenditure of money and, therefore, the responsibility for the program must be placed on a company official who has a voice in company policy-making and who can authorize expenditures. A competent specialist in industrial waste disposal should have direct control over all pollution abatement activities in the company.

Research personnel, in addition to working on problems of developing new products and improving yields, should devote time to waste recovery and use of by-products, and to development of suitable treatment methods for the unusable waste residue.

In new plant construction seven factors are listed for consideration. These include: (a) determination of local pollution control requirements; (b) study of the waste-diluting capacity of the receiving stream; (c) preparation of complete plans to meet local requirements for disposal of all sanitary sewage and industrial waste.

Under the heading of "Plant Operation," 18 suggestions are listed for attacking the waste disposal problem. The list covers the need for adequate personnel, collection of data through sampling and review of published literature, and keeping of records and reports. Cooperation with control agencies and interchange of technical information through technical societies or trade associations are recommended. Meetings of plant supervisory personnel followed up by letters and reports will serve to educate the key employees on the importance of waste recovery. This group also should be asked for suggestions for reducing the amount of waste. The need for treatment of sanitary wastes is not overlooked.

M. R. GOLLY

Eleventh Biennial Report of the State Water Commission (1944–1946), State of Connecticut. PUBLIC DOCUMENT NO. 78. 43 pp. (December, 1946).

A summary of studies undertaken and work accomplished by the Water Commission and cooperating agencies is given. Sections deal with waste surveys, needs for waste treatment, river sampling, stream gauging, flood control, and ground water.

A small woolen plant discharging wastes from the washing and dyeing of fabrics to a small brook flowing through a residential area was investigated. Analyses of effluent showed the following characteristics: pH, 7.2 to 8.7; suspended solids, 425 to 900 p.p.m., oxygen consumed, 1,100 to 1,900 p.p.m., and calculated 5-day B.O.D., 325 to 750 p.p.m. Experimental studies resulted in the recommendation of equalization and treatment of composites with 2 lb. of alum or ferrous sulfate per thousand gal., and the addition of sulfuric acid to give a final pH of 6.5. The color was either completely removed or so reduced that it became undetectible in dilutions obtainable in the brook. Reductions obtained after settling the treated waste for 2 hours were: for suspended solids, 95 to 98 per cent, and for oxygen consumed, 86 to 96 per cent. Chlorination after treatment removed little of the remaining color.

Studies were also made at a large felt manufacturing plant where the wastes contained wool grease, soap, sulfuric acid, dyes, sizing, oils used in raw stock lubricants, and waste fibers. A typical analyses

showed pH 6.8, total solids 1,528 p.p.m., volatile solids 464 p.p.m., suspended solids 208 p.p.m., oxygen consumed 460 p.p.m., and 5-day B.O.D. 235 p.p.m. Treatment with 1½ to 2 lb. of alum or ferrous sulfate per thousand gal. showed a 70 to 85 per cent reduction in volatile solids, and 80 to 96 per cent reduction in oxygen consumed.

A process has been worked out for concentrating dilute wastes from the pickling of brass by means of lime precipitation. Flow sheets are presented for a proposed plant to concentrate one million gal. daily of washwater, averaging 335 p.p.m. sulfuric acid, 76 p.p.m. copper, 86 p.p.m. zinc, and 40 p.p.m. tri-valent chromium. The system would consist of a collecting sump, Dorr clariflocculator, and an Oliver rotary vacuum filter. Lime fed through a wet feeder is to discharge directly to the thickener.

Some general costs of treatment for industrial wastes are also given on the basis of production or volume of wastes, but no details are included on the characteristics of the wastes or the treatment process. Chemical treatment has cost a textile mill 26 cents per ton of product, a woolen mill less than one-half of one per cent of the sale price of the cloth, a laundry 15 cents per thousand gal. of waste, and an iron fabricating concern, 25 cents per thousand gal. of waste water.

W. A. HASFURTHER

Black Warrior River Pollution Survey. By GILBERT H. DUNSTAN, Report of Engineering Experiment Station, College of Engineering, University of Alabama (38 pages).

This report covers the pollution survey of the Black Warrior River above Tuscaloosa, Alabama. Methods employed in making the survey and factors considered in evaluating the results are discussed. Conclusions concerning the degree of pollution observed and recommendations for abatement of pollution are presented.

The first part of the report, approximately one-third, deals with the definition of pollution, criteria for determining permissible pollution limits, and the purposes of pollution surveys.

S. C. MARTIN

Report of the Waste Conversion Committee. STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS. Mimeographed, 31 pages (March 5, 1948).

This report presents the work of a special committee appointed by the governor of Rhode Island under joint resolution of the General Assembly dated June 2, 1947 (No. 20, S 142). The task of this committee was "to study the processes and equipment necessary to convert sludge and other waste materials (vegetable and animal) into plant food or fertilizer, and all other byproducts and base materials for conversion to many other practical purposes." In the report, the special committee is referred to as the "Waste Conversion Committee." The committee was also instructed "to study the sewer systems of other cities and to recommend the setup of an authority to carry out any future plans for said recommendations."

The committee studied 11 waste, or potential waste, products ranging from sewage sludge to sawdust and other wood wastes. The report discusses each of these 11 waste, or potential waste, products in reference to their occurrence and possible conversion to useful purposes in Rhode Island.

The report consists primarily of a discussion of the conversion of sewage sludge to useful purposes, 21 of the 31 pages of the report being given over to this topic. The report includes a table showing the chemical composition of the following waste products: sewage sludge, animal manures, wool textile waste, organic fertilizer materials other than sewage sludge, and organic byproducts suitable for feeds and other fertilizers.

Except for the discussion pertaining to sewage sludge and its possibilities as a useful fertilizer and soil conditioner, little information of value is presented concerning the conversion of waste materials to practical uses.

S. C. MARTIN

Disposal of Water Purification and Softening Plant Wastes. A Preliminary Committee Report. *J. Am. Water Works Assn.*, **39**, 12, 1211–23 (Dec., 1947).

1. Lime and Lime-Soda Sludge Disposal. By WILLIAM W. AULTMAN. Sludge dis-

posal is a problem which is daily assuming greater importance for designers and operators of water softening plants using the lime or lime-soda method.

The sludge produced during the softening process consists principally of calcium carbonate, but contains varying amounts of magnesium hydroxide, aluminum hydroxide or other coagulants, and possibly colloidal material and organic matter removed from turbid waters. It is the minor constituents in the sludge which make the handling and disposal of this waste product more difficult.

The following four general methods are presently used for handling softening plant sludge:

(1) Lagooning to allow skimming or evaporation.
(2) Disposal by dilution in a large stream.
(3) Sludge drying or dewatering.
(4) Dewatering and calculation for recovery of lime.

Of these methods, the last one looks most promising for the future.

2. Brine Disposal from Sodium Zeolite Softeners. By Paul D. Haney. Wastes from sodium zeolite treatment plants consist of wash water containing the waste products of the regeneration cycle, plus unused salt. These waste products are composed principally of the chlorides of calcium and magnesium, together with small amounts of various compounds of iron and manganese. The effect of the chloride content on domestic and industrial water supplies, water for animals, aquatic life, and sewage treatment facilities is discussed.

A comparison is made of disposal of the brines by (1) evaporation ponds, (2) uncontrolled dilution, (3) controlled dilution, and (4) brine disposal wells. It is concluded that controlled dilution is most generally applicable for means of disposal, but even this method is unsatisfactory in many instances, as ample dilution is necessary. Therefore, because of the difficulties associated with the disposal of brine wastes, the use of the zeolite method as a means of softening municipal water supplies may often be precluded.

3. Disposal of Wash Water from Purification Plants. By Harry R. Hall. This report discusses the disposal of wash water and sludge discharged by conventional slow and rapid sand filter purification plants. These wastes contain only what was carried by the raw water, plus chemicals added in the treatment process. If treatment involves the use of such chemicals as iron compounds and activated carbon, changes in the color of the impurities result, while prechlorination reduces the bacterial count. In effect, then, the waste returning to the stream differs little from that of the stream itself, except that it is more concentrated.

Wash water turbidities vary during the wash from over 2,000 p.p.m. to 50 or 100 p.p.m. The question of the proper method of determination of contamination and pollution by such wastes is brought out, as no definite criteria appear to be available.

Eight methods of disposal are discussed.

Robert P. Lowe